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# Applications of the Virginia Statewide Land Cover Database

CASE STUDIES & USE CASE SCENARIOS

TINA SCHEIBE, JENNIFER ELLSWORTH

WORLDVIEW SOLUTIONS, INC. | 115 S. 15th St. Suite 400 Richmond VA 23219

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# Abbreviations

| **%ISA** | **Percent impervious surface** |
|---|---|
| **BMP** | Best Management Practice |
| **CBP** | Chesapeake Bay Program |
| **C-CAP** | Coastal Change Analysis Program |
| **CDL** | Crop data layer |
| **ConVision** | Conservation Vision |
| **CSI** | Cumulative and Secondary Impacts |
| **CZM** | Coastal Zone Management |
| **DCR** | Department of Conservation and Recreation |
| **DEQ** | Department of Environmental Quality |
| **DOF** | Department of Forestry |
| **E-GIS** | Environment and energy Geographic Information System |
| **EIS** | Effective impervious surface |
| **EPA** | Environmental Protection Agency |
| **ESV** | Ecosystem service value |
| **GIS** | Geographic Information System |
| **HRPDC** | Hampton Roads Planning District Commission |
| **MS4** | Municipal Separate Storm Sewer System |
| **NGO** | Non-governmental organization |
| **NHP** | Natural Heritage Program |
| **NIS** | Noneffective impervious surface |
| **NLCD** | National Land Cover Database |
| **NMP** | Nutrient Management Program |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NPDES** | National Pollutant Discharge Elimination System |
| **NPS** | Nonpoint source |
| **NRVRC** | New River Valley Regional Commission |
| **NWI** | National Wetlands Inventory |
| **PCA** | Priority Conservation Areas |
| **PDC** | Planning District Commission |
| **RBZ** | Riparian buffer zone |
| **RPA** | Resource Protection Area |
| **RRPDC** | Richmond Regional Planning District Commission |
| **RRRC** | Rappahannock-Rapidan Regional Commission |
| **RVARC** | Roanoke Valley-Alleghany Regional Commission |
| **RWLCD** | Rivanna Watershed Land Cover Dataset |
| **SOC** | Soil organic carbon |
| **SWCD** | Soil and Water Conservation District |
| **TMDL** | Total Maximum Daily Load |
| **TNC** | The Nature Conservancy |
| **UHI** | Urban heat island |
| **USACE** | United States Army Corps of Engineers |
| **VaNLA** | Virginia Natural Landscape Assessment |
| **VBMP** | Virginia Base Mapping Program |
| **VGIN** | Virginia Geographic Information Network |
| **VPDES** | Virginia Pollutant Discharge Elimination System |
| **VSLCD** | Virginia Statewide Land Cover Database |
| **VSMP** | Virginia Stormwater Management Program |
| **WIP** | Watershed Implementation Plan |

## Abstract

The availability of accurate, relevant land cover data presents opportunities for geographic analysis, management, and monitoring for public and private entities alike. Copious amounts of research and management practices have been developed by both policymakers and academic researchers with the aid of existing land cover data, such as the National Land Cover Database (NLCD), as controls or inputs. These efforts include, but are not limited to, agriculture, forestry, urban development, and wildlife models. The introduction of the high resolution Virginia Statewide Land Cover Database (VSLCD) presents new and exciting opportunities to state and local governments, non-governmental associations, and federal entities. This paper describes potential applications of the land cover dataset by providing background on the development of the project, a summary of the potential applications of this dataset to address current state and local government needs, and an introduction to land cover data uses presented via a series of case studies.

## Introduction

Effective land use planning requires information on existing land use patterns and changes in those patterns over time. Many methods have been developed to map land cover from satellite imagery, but improvements have developed slowly relative to the rapid advancement of high-resolution aerial imagery. Studies suggest that the accuracy and resolution of land cover data directly correlates with the quality of outputs; therefore, the creation of improved land cover datasets proves valuable. Furthermore, a single standardized land cover product is preferable to a conglomeration of data from a variety of sources, as these data may be incompatible due to the problem inherent in inconsistent classification systems, redundant due to lack of coordination of data collection efforts, temporally inconsistent, or of varying quality (Anderson, et al. 1976).

Prior to the release of the VSLCD, the latest available statewide land cover data in Virginia were from the 2011 NLCD. The NLCD is a freely available dataset covering the entirety of the United States, developed by the Multi-Resolution Land Characteristics Consortium, and released as a set of 20 classifications at 30-meter resolution. Updated on a 5-year cycle, the NLCD is designed for general applications in biology, climate, disease analysis, land management, hydrology, environmental planning, and telecommunications. Formal accuracy assessments of the NLCD are released at the regional level, and are typically estimated at around 80%; however, the statewide accuracy of certain classes has been found by independent studies to be less than 10%, as in the case of shrubland in Kansas (Wardlow and Egbert 2003). Although the NLCD agrees with many detailed land cover datasets at large scales, comparisons at local scales offer less consistent results (White 2011). The increased level of detail represented by the VSLCD is expected to improve upon the NLCD, especially in developed areas characterized by complex land cover patterns (Figure 1).

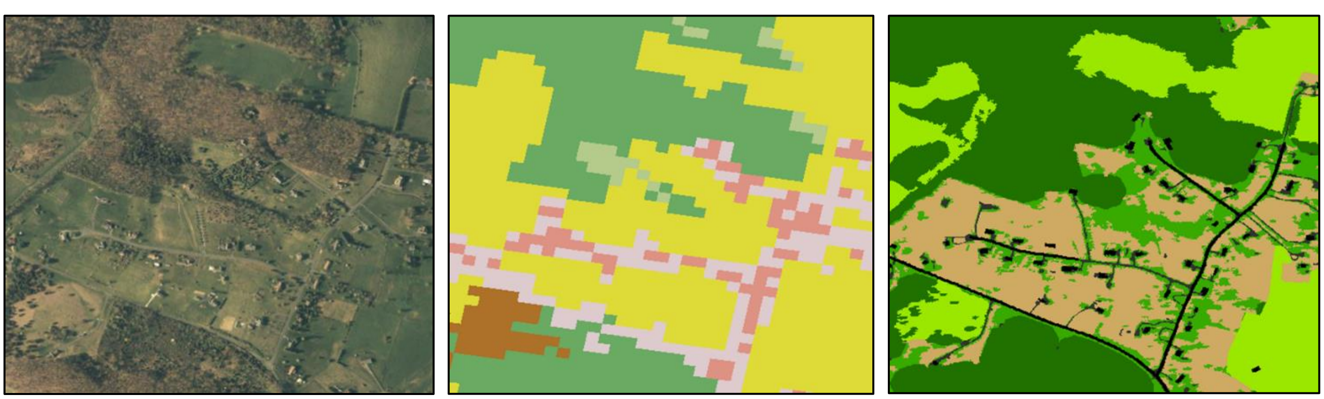

*Figure 1. VBMP imagery, 30-meter NLCD, and one-meter VSLCD.*

The VSLCD leverages high-resolution imagery provided by the Virginia Base Mapping Program (VBMP) for automated feature extraction, followed by additional remediation and development using state and local reference data. Combining automated and manual data development efforts provides a higher quality land cover portrayal as well as a more accurate representation of the land cover classifications. This method ensures accuracy and allows users to engage in analysis without concern over the validity of the data for several years after release, at which point some data may already be inaccurate. For further information on the methodology used to develop the VSLCD, please see the project's Technical Plan of Operations, available from the Virginia Geographic Information Network (VGIN).

## Background

During its 2014 session, in order to support implementation and enforcement of the Virginia Stormwater Management Act, the Virginia General Assembly enacted new Virginia Stormwater Management Program (VSMP) Regulations, which require the Department of Environmental Quality (DEQ) to establish a VSMP for any locality that neither establishes its own program nor operates a municipal separate storm sewer system (MS4). DEQ also serves as the lead agency for the Coastal Zone Management (CZM) Program, a network of state agencies that administer state laws and policies to protect and enhance coastal resources. Virginia's CZM Program includes everything from wetlands laws to sustainable economic development. Other agencies in the network, forming the Coastal Policy Team, include the Department of Conservation and Recreation (DCR) and eight Coastal Planning District Commissions (PDCs). Part of the CZM is a grant program that provides federal funds to implement approved coastal management programs. Every five years, a number of enhancement areas are evaluated for this funding and ranked based on priority. From this, a five-year plan is developed and submitted for approval from the National Oceanic and Atmospheric Administration (NOAA), and specific grant projects are developed.

In 2015, one of the program's top priority areas was Cumulative and Secondary Impacts (CSI) of coastal growth and development based on continuous increases in population and demand for coastal land. Out of the CSI came a Land and Water Quality Protection Plan to address urban, suburban, and rural impacts on the coasts. These efforts focused on improving stormwater management by evaluating the regulatory impacts of new legislation and Chesapeake Bay Total Maximum Daily Loads (TMDLs), modeling impacts of various development scenarios on water quality, and identifying enforceable policy tools to assist localities with the reduction of nutrient loadings outlined in the Chesapeake Bay TMDL Watershed Implementation Plan.

On June 16, 2014, the governors of Bay headwater states signed the Chesapeake Bay Watershed Agreement committing to full participation in the Bay Program and collaboration between states to achieve the outlined goals for restoration of Bay waters and surrounding lands. The Chesapeake Bay Program's Goal Implementation Teams committed to developing strategies for achieving outcomes and coordinating actions among partners and stakeholders within one year. The 2015 CZM Needs Assessment stated that action would likely be required by Virginia in subsequent years to meet commitments and achieve those outcomes outlined in the Watershed Agreement. It also asserted that there are currently no studies illustrating the effectiveness of Virginia's management efforts to address the CSIs of coastal development. Stakeholders at the local, state, and federal level wanted to develop a strategy that would align priorities in land use and land protection for maximum socio-economic and ecological benefit and create a shared vision for economic growth and conservation. Part of this strategy included a Virginia Natural Landscape Assessment Update, which relies on land use data as one of the model inputs. With new federal funding from an Environmental Protection Agency (EPA) Chesapeake Bay Regulatory and Accountability Program Grant, the Chesapeake Bay Program (CBP) is calibrating an updated version of their Watershed Model. The DEQ, among others, also contributes funding to VGIN for regular VBMP updates, which acquires statewide digital orthography on a four-year cycle. Among the goals of this effort include providing a consistent base map against which local government spatial data can be developed and maintained, and improving the availability of adequate land cover data to assist localities in planning and implementing stormwater management programs. This sequence of events revealed a need for an updated land cover database for Virginia, and ultimately served as the catalyst for development of the VSLCD from 2013/2016 VBMP imagery.

# 1. Land Cover Use Cases

## 1.1 Impervious Surfaces

The tabular data accompanying the VSLCD provides percent impervious surface area (%ISA) estimates at the county level that are expected to be more credible than estimates derived from lower-resolution, lower-accuracy land cover datasets. The NLCD has been found in the past to be reliable for estimating %ISA but only when paired with population density data (Civco, Chabaeva and Hurd 2006). Furthermore, estimates based on vegetation indices, which have been found to have an inverse relationship with %ISA, are affected by seasonal changes, the presence of bare soils, and effects from tree shadow and tree canopy overhanging roads (Yuan and Bauer 2007, Kaspersen, Fensholt and Drews 2015). Impervious surface area is an indicator of urban disturbance and population growth, which correlate with deterioration of air and water quality, increases in flood severity and frequency, and disruption of biophysical processes; however, urban surface cover is highly variable even at highly localized scales, so the accurate quantification of %ISA requires high-resolution information (Kaspersen, Fensholt and Drews 2015). Figure 2 shows an example of the dense impervious surface cover that is characteristic of urban areas. Distinctions between various urban land covers, such as turf, tree, barren, and impervious, at this level of detail is not possible with the NLCD.

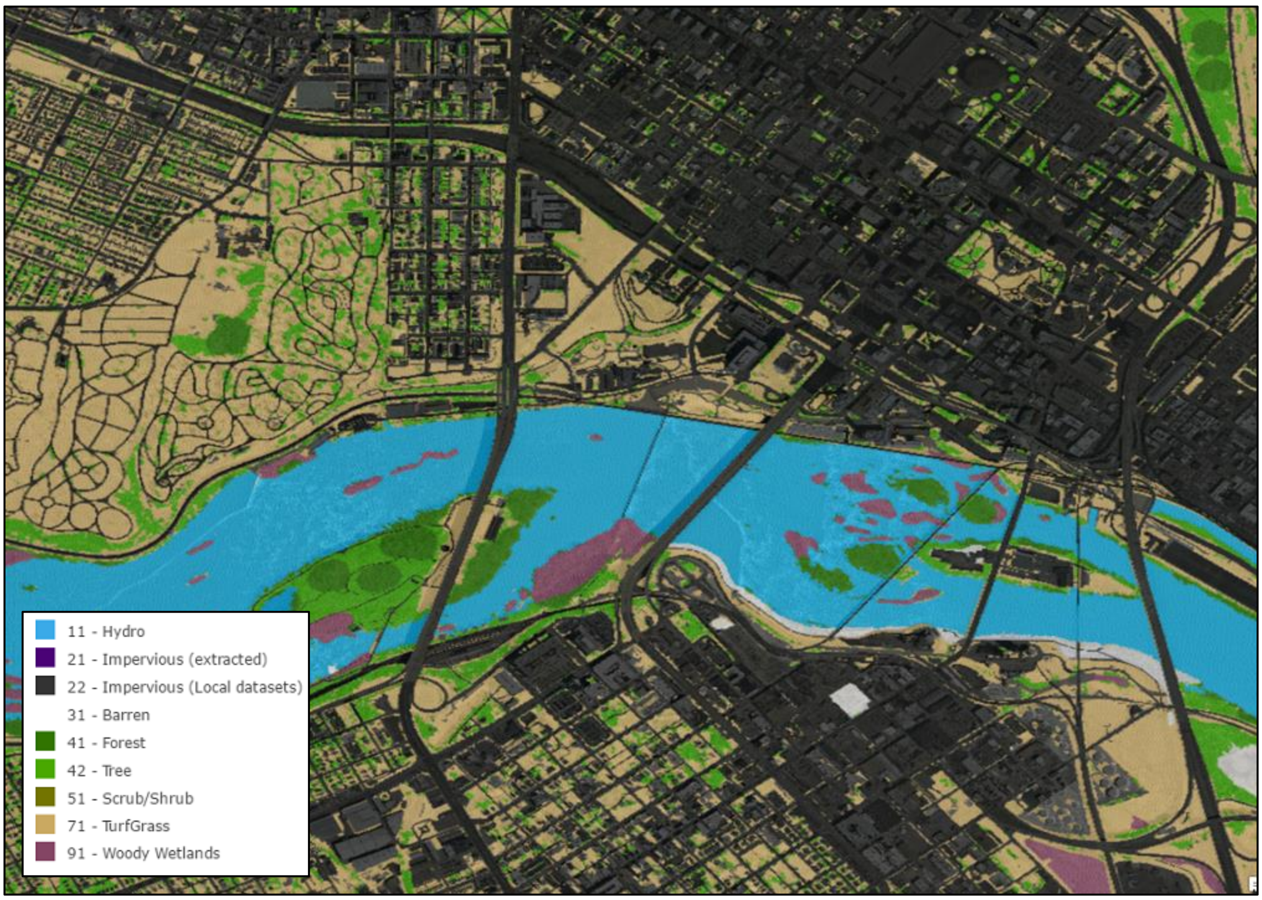


*Figure 2. Dense impervious surface cover in downtown Richmond, Virginia (VSLCD).*

Highly developed areas modified by increasing impervious cover, which absorbs and reradiates solar radiation, will experience higher overall temperatures, known as the urban heat island (UHI) effect, which is further exacerbated by the high density of anthropogenic heat sources in urban areas. The radiation of heat from the Earth is essential in controlling both surface heat and atmospheric water exchange; thus, the UHI effect results in a deteriorated living environment, higher energy consumption, increased levels of pollution, and even changes in precipitation patterns (Memon, Leung and Chunho 2008, Yuan and Bauer 2007). The UHI effect can be studied in a spatial context by correlating urban heat patterns with urban surface cover (Yuan and Bauer 2007). Accurate characterization of the surfaces in the urban environment is a critical first step in working towards mitigation strategies such as living roofs, curbside planting, urban greenspaces, and lighter surfaces (Akbari, Rose and Taha 2003, Memon, Leung and Chunho 2008).

The expansion of impervious cover also has an impact on soil health and carbon management. When impervious surfaces are constructed, vegetation and topsoil are removed and the soil is compacted and sealed, which inhibits atmospheric exchange of water, gases, and biomass. This has a deleterious effect on soil organic carbon (SOC) content, an important part of the global carbon cycle and a key aspect of soil fertility. Studies have found that SOC content under impervious surfaces is significantly lower as well as differently distributed compared to SOC content under adjacent pervious surfaces (Yan, et al. 2015). When the soil is not able to store carbon, it ends up in the atmosphere where it contributes to global warming and climate change. Moreover, compactness of the soil increases under impervious surfaces to a level that can drastically reduce root growth (Yan, et al. 2015). If, in the future, an area of developed land is converted back to a rural land use, detailed knowledge of the previous distribution of impervious surfaces in that area can assist in soil remediation planning. More presently, any agency or organization that studies climate change can refer to the VSLCD during an analysis of the carbon sequestering capacity of Virginia's soils.

Impervious surfaces associated with urbanization are correlated to water quality indicators. Pollutants gather on impervious surfaces, such as motor oil on roadways, and after a rain event can enter waterways via runoff. A study in China found that as the degree of urbanization increases, various chemical, biological, and metal indicators of low water quality increase exponentially, while dissolved oxygen decreases exponentially (Liu, Wang and Li 2013). In the same study, the average threshold value of %ISA that indicates unavoidable degradation of water quality was found to be about 37% with any value beyond 40% indicating severe degradation. With these thresholds in mind, localities may use the provided %ISA estimates to support evaluations of local water quality and to assist in stormwater management planning.

### 1.2 Stormwater Management

Impervious surface cover has detrimental consequences on the hydrologic system due to increased volume, duration, and intensity of surface runoff with consequent pollutant loading and water quality degradation thereby necessitating stormwater management. Stormwater runoff is a serious issue in areas with high imperviousness, as water will travel across surfaces rather than infiltrating into the soil, carrying chemical and biological pollutants from roads, roofs, and parking lots into waterways, thus impacting hydrology, stream habitat, and water quality (Civco, Chabaeva and Hurd 2006). Both the amount of runoff and its resulting impact on water quality are correlated to %ISA; therefore, calculating %ISA is a necessity for many localities to meet EPA reporting requirements to discharge stormwater under the National Pollutant Discharge Elimination System (NPDES). Besides impervious surface, knowledge of not only the total area, but also the spatial distribution of various land cover types is necessary to develop a complete stormwater model due to the various impacts different types of cover have on rainwater infiltration and stormwater runoff rates (Pauleit and Duhme 2000). One method of hydrologic modeling, known as TR-55 modeling, is used by water resource planners to calculate runoff volume, peak discharge, hydrographs, and minimum storage volumes and requires accurate land cover data among its inputs (Stavros Calos, e-mail to author, July 21, 2016). Of interest is not only impervious surface, but also open space, cropland, pastureland, and forested land.

Currently, stormwater management techniques often rely on land cover information provided by the NLCD, most recently available for 2011 and without a publicly available accuracy assessment. The VSLCD tabular data will provide localities with figures that are both more recent and more reliable and will allow policy makers, urban planners, and locality constituents to better manage the effects of stormwater runoff. One such management technique is green infrastructure (section 1.4.1), such as rain gardens, bioswales, and permeable pavement, which harnesses the natural ability of vegetation and soil to counteract the negative impacts of increasing %ISA by improving water quality and mitigating flooding. As spatial arrangement is key to its effectiveness, detailed land cover data are necessary to accurately represent complex forest-urban watersheds at various scales from street-level to watershed-level (Stueve, et al. 2015). Because the NLCD lacks sufficiently fine resolution to interpret detail at the street or block level, the VSLCD will be in an invaluable resource in this domain. For an example of the use of land cover data in stormwater management planning, see section 3.1.1.

## 1.3 Urban Planning

Not only does the VSLCD provide a powerful resource for urban planning and modeling, it provides a more holistic, comprehensive view of the urban environment for sustainability planners whose outlook often becomes fragmented by the opposing influences of multiple stakeholders. Since urban land cover influences air temperatures, surface runoff, and pollution loading, setting standards at the land cover level would simplify the process of developing and abiding by environmental regulations by providing a framework for more detailed planning (Pauleit and Duhme 2000). Additionally, other attributes of urban areas, such as resource consumption data, can be aggregated at the land cover level to facilitate analysis.

### 1.3.1 Urban Sprawl

When urban areas become very extensive and residential areas begin to spread out across the landscape, urban and suburban sprawl results. Sprawl causes economic, environmental, and social strain on many communities in the forms of traffic congestion, higher public service costs, increased pollution, biodiversity decline, invasion of non-native species, and loss of open space.


*Figure 3. Extensive urban sprawl in Northern Virginia (VSLCD).*

In Northern Virginia in particular (Figure 3), where several counties are among the fastest growing in the United States, the capability to monitor and model this sprawl with high-resolution data could prove useful, particularly for transportation and infrastructure planning (Li and Shao 2014). A simple comparison of the land cover composition of a predominantly urban/suburban county in Northern Virginia (Figure 4) to that of a neighboring, predominantly rural county (Figure 5) reveals the stark shifts in land cover that occur as a result of urban sprawl.

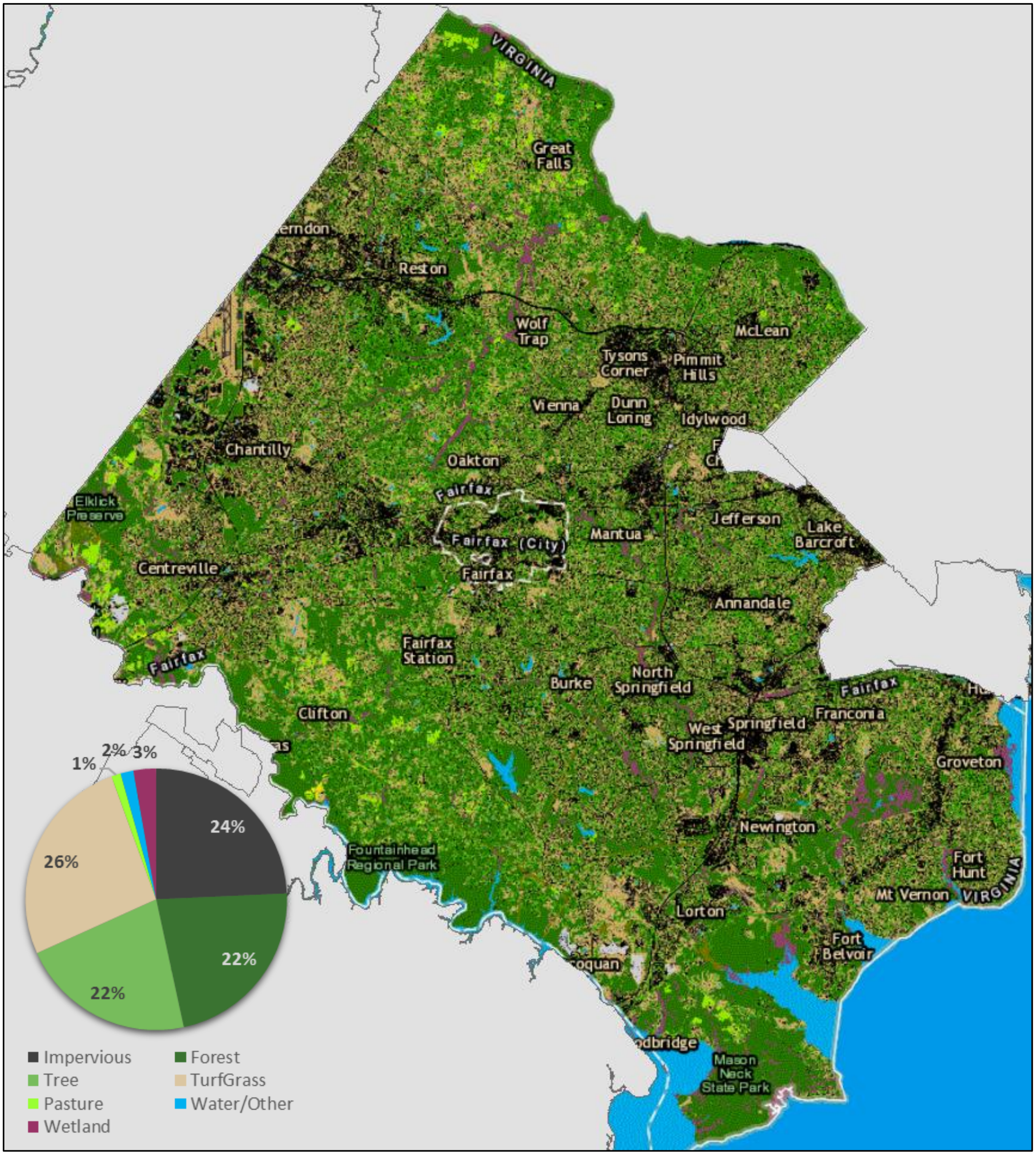


*Figure 4. Land cover for Fairfax County (VSLCD).*


*Figure 5. Land cover for Loudoun County (VSLCD).*

Lower-resolution land cover maps like the NLCD have been used to delineate the urban area of a city, but it has been determined that high-resolution data are necessary to identify pockets of sprawl within larger urban areas as well as to avoid classification errors caused by mixed pixels in suburban areas (Sutton 2003, Epstein, Payne and Kramer 2002). The NLCD in particular is not ideal for this application due to its tendency to underestimate low-density development outside urban areas, which is a critical component to accurately measuring urban sprawl (Irwin and Bockstael 2007). When a high-resolution dataset is compared to the NLCD, there is often significant disagreement among several classes, particularly in complex urban areas where land cover varies widely over even small distances (Stueve, et al. 2015).

A convenient method of monitoring urban sprawl over time is with change detection analysis, in which two datasets covering the same area at different points in time are compared. For example, a change detection study of the Greater Toronto Area using land cover data derived from Landsat TM imagery discovered significant urban growth between 1985 and 2005 (Furberg and Ban 2012). As this study was not based on high-resolution imagery, it could only identify large-scale trends. With future updates to the dataset, the VSLCD could easily be leveraged for monitoring urban sprawl at smaller scales. For more on change detection, see section 4.1.

### 1.3.2 Urban Modeling

Up-to-date land cover information is typically critical to implementing existing urban planning models, and implementing the VSLCD may be preferred to other sources due to the high spatial resolution and accuracy thresholds. Urban models such as The Environment and energy Geographic Information System (E-GIS) for urban energy modeling or WaterSim for urban water planning are examples of types of models that could integrate the VSLCD. E-GIS was developed to support environmentally conscious urban planning by integrating urban planning information, including land cover, with energy planning information (Yeo, Yoon and Yee 2013). This model can predict consequences of urban development including temperature and energy consumption. WaterSim is a simulator that investigates how changing various factors such as climate conditions, population growth, and policy decisions, would affect water supply and demand in Phoenix, AZ, and land cover is a key input in these types of simulations (Gober, et al. 2011).

### 1.3.3 Sustainable Development Planning

The VSLCD will inform sustainable development such as in planning for urban greenspaces and urban agriculture. It has been shown that uniform spatial distribution and connectivity of greenspaces throughout the urban environment are key for delivering ecological, social, and economic benefits (Li, et al. 2005). Among these benefits are carbon sequestration, lowering of building temperatures, mitigation of the UHI effect, and improved urban environment (Yi and Haoyang 2014). Identification of brownfields that have great potential to serve as future greenspaces also becomes easier with these data. Urban agriculture projects, such as agricultural green roofs and community gardens, have become the frontier of sustainable development and urban greening. Urban agriculture satisfies both the need for sustenance and the desire for access to nature felt by urban residents (Yi and Haoyang 2014). All such planning efforts will be assisted by the VSLCD.

## 1.4 Conservation Planning

Beyond usage for urban planning practices, the VSLCD will also be adapted for use in conservation efforts such as greenway planning, riparian buffer analysis, and nutrient management. By providing consistent land cover information for all of Virginia, the VSLCD will provide capability for the remote designation of conservation measures to localities without robust geospatial information and provide an additional source for reference in localities with existing geospatial capabilities.

### 1.4.1 Green Infrastructure Planning

Habitat fragmentation, particularly in forests, is one of the main factors driving native species loss by interrupting various natural processes including animal migrations, predator-prey interactions, pollination, and nutrient cycling (Heilman Jr, et al. 2002). For example, various studies have found that urbanization-driven fragmentation reduces the abundance of, inhibits the movements of, and could possibly lead to local extinction of amphibians, which are an important ecological indicator (Price, et al. 2004). Habitat fragmentation can be spatially defined in three ways: loss of original habitat, reduction in habitat size, and isolation of habitat patches (Furberg and Ban 2012).

Green infrastructure planning is the main strategy for mitigating the deleterious effects of fragmentation. One such strategy consists of establishing and maintaining greenways, which are corridors of land and open space that provide increased habitat connectivity while simultaneously providing recreational opportunities such as parks and hiking trails. A large, interconnected network of greenways reduces isolation of habitat patches and enables species migrations and genetic exchange between patches. Examining spatial patterns of land cover is key in detecting both forest fragmentation and greenway connectivity. A proper assessment of habitat structure requires significantly more detail than can be provided by low-resolution land cover datasets such as the NLCD, which significantly underestimates land fragmentation in exurban areas (Riitters 2005, Irwin, Hyun and Bockstael 2006). The high-resolution VSLCD fills this gap. For examples of local and regional green infrastructure planning projects, see sections 3.2 and 3.3.

### 1.4.2 Resource Protection Areas

Resource Protection Areas (RPAs) are protected under state law and local ordinances from development and tampering to ensure the protection of water quality and safety within Virginia. RPAs often consist of riparian buffer zones (RBZs): the vegetated filter strips along streams, rivers, and lakes. RBZs are important natural features that provide unique biological spaces and can be derived from the land cover classes in the VSLCD. They serve as nutrient control mechanisms by filtering nutrient and sediment loads from both agricultural and urbanized sources. The roughness of vegetative cover reduces the speed of runoff flow and encourages sediment deposition and water infiltration. Additionally, plants and bacteria in RBZs take up nutrients in runoff, thus reducing downstream loading rates (Narumalani, Zhou and Jensen 1997). By assessing their current distribution, RBZs can be restored or expanded to ensure they achieve maximum effectiveness. Evidence suggests that RBZ restoration in the Piedmont region has the greatest potential for reducing overall nutrient inputs to the Chesapeake Bay (Weller, Baker and Jordan 2011). The same study found that up to 2.7 times more nitrate could be removed if all gaps in RBZs downhill from croplands in the Chesapeake Bay watershed were restored.

The existence of a finer-resolution, more accurate, and more frequently updated dataset will greatly enhance efforts to conduct riparian buffer analysis, which aids in hydrological assessments, water resource planning, and resource management (Goetz 2006). In one example of a GIS-based RBZ analysis, the stream network of the study area was extracted from a land cover dataset, and then Soil Capability data, which classify soils by agricultural suitability, were used to delineate buffer zones and to identify unprotected areas (Narumalani, Zhou and Jensen 1997). By overlaying GIS data layers containing existing RBZs and desired RBZs, discrepancies between them can be calculated (Xiang 1996). Land cover data provide a reference for feasibility assessments during RBZ development, especially in urban and suburban areas where roads and buildings may occur within the RBZ and impede seamless restoration. Although the NLCD has been used with success to identify forest cover in the riparian buffer zone as the main variable explaining phosphorus and sediment loading in streams in the mid-Atlantic region, monitoring and assessing current buffer statistics is difficult without access to high-resolution, high-accuracy data (Goetz 2006). This is because the coarse resolution of 30-meter data is inadequate for the detection of narrow features like RBZs (Narumalani, Zhou and Jensen 1997). On the other hand, the one-meter resolution of the VSLCD is ideal for this application. For an example, see section 3.1.3.

### 1.4.3 Nutrient Management

The VSLCD will afford nutrient management planners a more comprehensive view of the watershed, particularly in terms of landscape features that mitigate nutrient transport and processing. Nutrient management is critical to avoiding the eutrophication that results when large quantities of nitrogen and phosphorus are delivered downstream from agricultural fields or urban surfaces into a receiving waterbody. Eutrophication not only hinders recreation and reduces the aesthetic quality of the waterbody, but also leads to a low-oxygen condition known as hypoxia, which degrades the aquatic habitat. In the Chesapeake Bay area, row crop agriculture is the largest cause of nutrient loading and eutrophication (Weller, Baker and Jordan 2011).

Typically, nutrient management techniques are focused at the field and farm scale, but having access to landscape-level data will enable a more effective, geographically targeted approach. It has been found that landscape features that affect nitrogen transport and processing, also known as nitrogen sources and sinks, are comparable to nitrogen application rates in determining downstream loading rates (McLellan, Schilling and Robertson 2015). Many nitrogen sinks, such as wetlands and riparian buffers, can be derived from the VSLCD, which could also be subdivided by hydrologic unit to provide useful areas of focus for nutrient managers.

Composition of the landscape plays a large role in nutrient loading. It has been found that unmanaged forest cover, a nutrient sink, contributes least to nutrient loading, agricultural cover contributes significantly more than forest cover, and impervious cover contributes significantly more than all pervious cover types combined (Schoonover and Lockaby 2006). Therefore, conversion of pervious land cover, like forest and agriculture, to impervious urban land cover plays a major role in water quality problems. Furthermore, although simple land cover proportions can accurately predict nutrient loading in large watersheds, the spatial arrangement of land cover may play a stronger role in smaller watersheds or when looking at larger watersheds at a local scale (Zhang and Yang 2013). Furthermore, nutrient management can be more cost-effective when management efforts are concentrated at the so-called “critical source areas” that contribute disproportionately to overall nitrogen loading (McLellan, Schilling and Robertson 2015). The VSLCD will assist in identifying such areas.

### 1.4.4 Ecosystem Services

Ecosystem services, the benefits that the environment provides to humans, are too often ignored during land use planning due to the difficulty of assigning a dollar value to natural capital (de Groot 2006). The natural environment not only provides products, such as food, timber, and medicine, but also services, such as nutrient recycling, soil retention, carbon sequestration, waste assimilation, recreation, and aesthetic scenery. Mapping and quantifying ecosystem service value (ESV) is critical when prioritizing land for conservation and when making decisions concerning future land conversions.

Land cover data have been used in several studies to visualize and quantify the total ESV provided by an area. The general methodology involves assigning ESVs to land cover types and then linking that information to a land cover dataset to create a map (Burkhard, et al. 2009). Existing inventories of services, such as the list compiled by de Groot (2006) or the matrix created by Burkhard et al. (2009), can inform the initial assignment of values. In general, undisturbed environments (Figure 6) provide the highest value of services while highly modified environments (Figure 4) provide little or no value (Burkhard, et al. 2009).

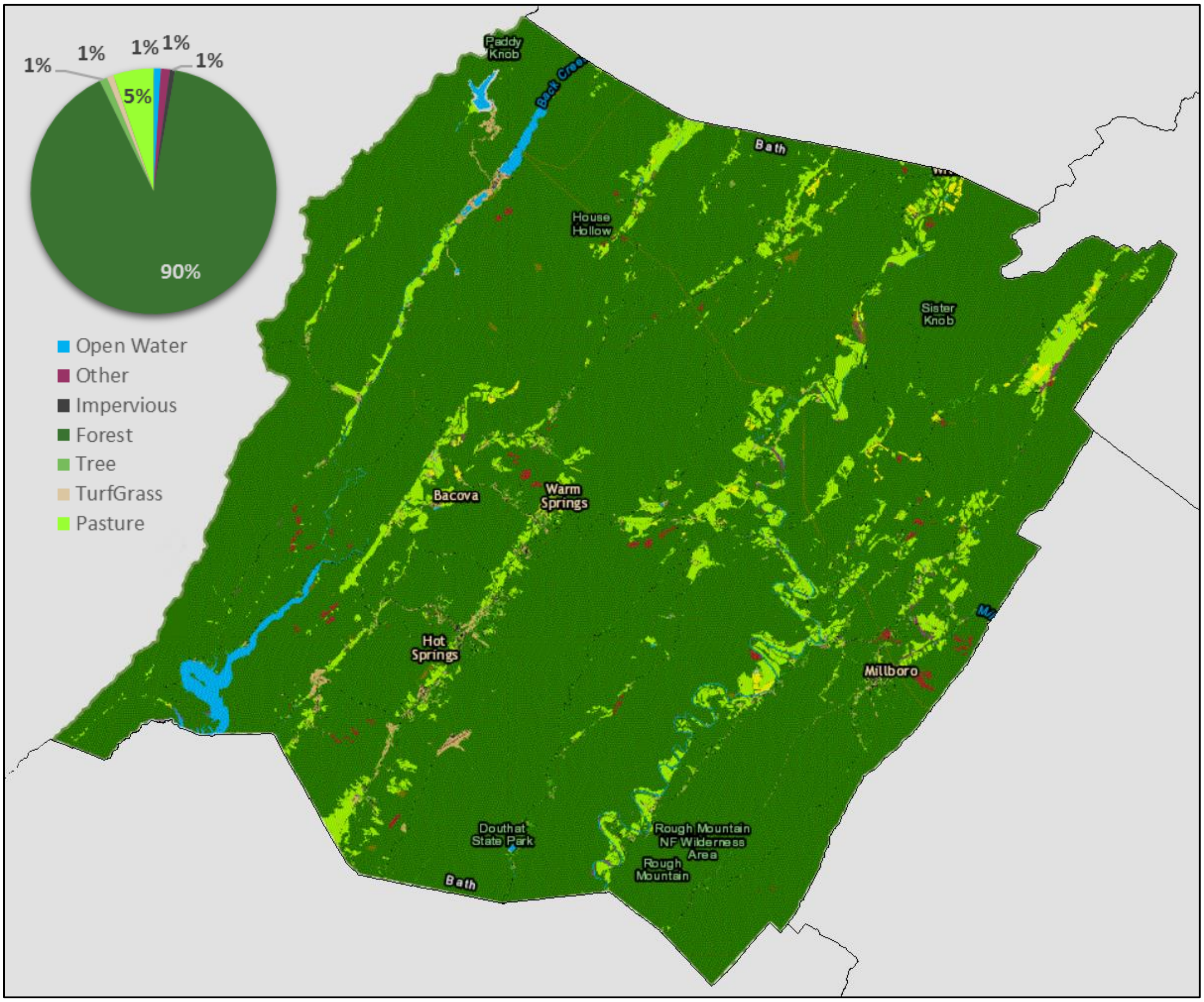


*Figure 6. Land cover for Bath County (VSLCD).*

The value of a given ecosystem service can either be expressed as a dollar value (Troy and Wilson 2006) or a rank value (Burkhard, et al. 2009). Several methods for determining the dollar value of an ecosystem service are described by de Groot (2006). The formula for deriving the total ESV of a given cover type consists of summing the annual value of all services per unit area provided by a land cover type and multiplying by total area of the land cover type (Troy and Wilson 2006). If this calculation is performed for all cover types in an area, a total ESV can be determined. This process can then be repeated for a hypothetical future land cover scenario based on proposed land conversion or restoration, projected growth, or the occurrence of a natural disaster. If land cover data are available for multiple points in time, changes in total ESV can be monitored and correlated to observed land cover changes. Using any of these methods, land use planners and conservation planners alike can employ the VSLCD to map, quantify, and possibly monitor the value of ecosystem services provided by the landscape of Virginia.

## 1.5 Subclassification

The VSLCD classifications provide general information regarding land cover, but with the help of external raster or vector data, these general classes can be subdivided into more detailed classes in order to better serve the needs of individual users. For example, users can refine the agriculture classes provided by the VSLCD using the detailed crop subclasses provided by the Crop Data Layer (CDL) from the National Agricultural

Statistics Service either by simply overlaying the datasets or by leveraging geoprocessing tools to create a new combined dataset. This new dataset would provide both the high resolution and accuracy of the VSLCD and the detailed crop classifications of the CDL. The ways in which the VSLCD can be subclassed are as varied as its potential applications. The forest class can be separated into urban and rural or into deciduous and coniferous classes. The impervious class can be subdivided by levels of development density or by zoning. The turf class can be subcategorized by slope, soil type, or land use. Using any of these processes, localities can manipulate existing data to meet their specific needs without having to gather resources to create completely new geospatial information.

One example of a modeling approach that would benefit from access to a dataset like the VSLCD outlines a two-step method for subclassification of impervious surface features as either effective or noneffective for the purposes of urban hydrologic modeling (Han and Burian 2009). Effective impervious surfaces (EIS) follow an exclusively impervious path to downstream stormwater collection systems while noneffective impervious surfaces (NIS) drain onto nearby pervious surfaces. Knowledge of EIS estimates allows for more accurate modeling of stormwater runoff volumes and rates. The first step in this approach is to perform a land cover classification to identify pervious and impervious surfaces in an urban area. Once land cover data has been developed or procured, each impervious pixel is subclassified as either EIS or NIS using a digital elevation model in conjunction with a vector dataset identifying locations of stormwater infrastructure. Having the VSLCD available makes the first step unnecessary and allows future studies to be conducted more quickly and cost-effectively.

# 2. Federal and Statewide Modeling Inputs

The VSLCD is more than an alternative to the NLCD for geographic analysis within Virginia. The increased spatial resolution, manual remediation, and additional locality-provided references used in the VSLCD should offer improved accuracy and credibility in a variety of situations while maintaining a similar level of classification variety. When the idea to develop the product was introduced, a number of state and local agencies whose current initiatives included land cover input from NLCD and other resources reached out as potential users of the new dataset. Additionally, VGIN identified a list of prospective users who were then contacted in regards to their plans for the VSLCD. These case studies are presented over the following two sections.

## 2.1 Department of Defense

The United States Department of Defense highly values accurate geospatial data of military installations. Initiatives such as the Centralized Geospatial Data Collection Effort, seeks to combine independent geospatial data sources on Army installations into a single project in order to reduce overall costs of data collection and management. There are 30 installations within Virginia, and for those interested in improving or beginning to develop geospatial data, the VSLCD will provide a useful reference.

A growing concern for both military installations and the communities they exist within is encroachment - the impact of increasing urban and rural development on the ability of the military to train and function properly - as well as the impact of military training and land use on the local community and surrounding environment. Encroachment is a large enough problem that many local governments communicate directly with installation management on plans for new development and expansions. Encroachment is measured and reported by the Encroachment Condition Module, a GIS tool for which the VSLCD could provide a useful resource. In Figure 7 below, Fort Lee, the third largest training site in the Army, is bordered to the west by Colonial Heights, to the southwest by Petersburg, and to the northeast by Hopewell.


*Figure 7. Land cover for Fort Lee (near center)*
*surrounded by Colonial Heights, Hopewell, and Petersburg (VSLCD).*

This is one example of the VSLCD providing geospatial information inclusive of military installations and their surroundings in a single product, whereas local datasets and military datasets may not always be congruent for analysis.

## 2.2 Department of Environmental Quality

Under the federal Clean Water Act, the Virginia Pollutant Discharge Elimination System (VPDES) permitting program controls point source pollution by regulating Municipal Separate Storm Sewer Systems (MS4s), industrial discharges, and construction activities. The goal of these regulations is to reduce the discharge of point source pollutants into local waterways, for these pollutants not only cause damage to the streams they initially enter, but also negatively impact water quality in the ultimate receiving body, which is the Chesapeake Bay for the majority of Virginia. In this state, [MS4] fees and permitting decisions are administered by the DEQ based on %ISA and runoff estimates provided by localities in conjunction with [TMDL] data developed by DEQ. TMDLs specify the total maximum daily pollution load that a waterbody can receive before becoming impaired. There is significant desire at DEQ to use this new LULC data for TMDL Project development and TMDL Implementation Plan development (Bill Keeling, e-mail to author, November 17, 2016).

More localities are becoming interested in using GIS to assist in stormwater management, and the VSLCD could provide a convenient entry point to do so. Currently, areas with insufficient geospatial information are more difficult to regulate. The localities may have difficulty providing an accurate impervious surface breakdown, and DEQ lacks sufficient resources to verify all provided estimates (Jaime Bauer, phone call with Brandon Wheeler, May 9, 2016). Furthermore, datasets collected from various localities may not only differ in methodology and accuracy, but might also be temporally inconsistent. The VSLCD offers reliable data for localities to determine their own %ISA (Figure 8), with the additional benefit of allowing DEQ to easily cross-reference data provided to them by localities.

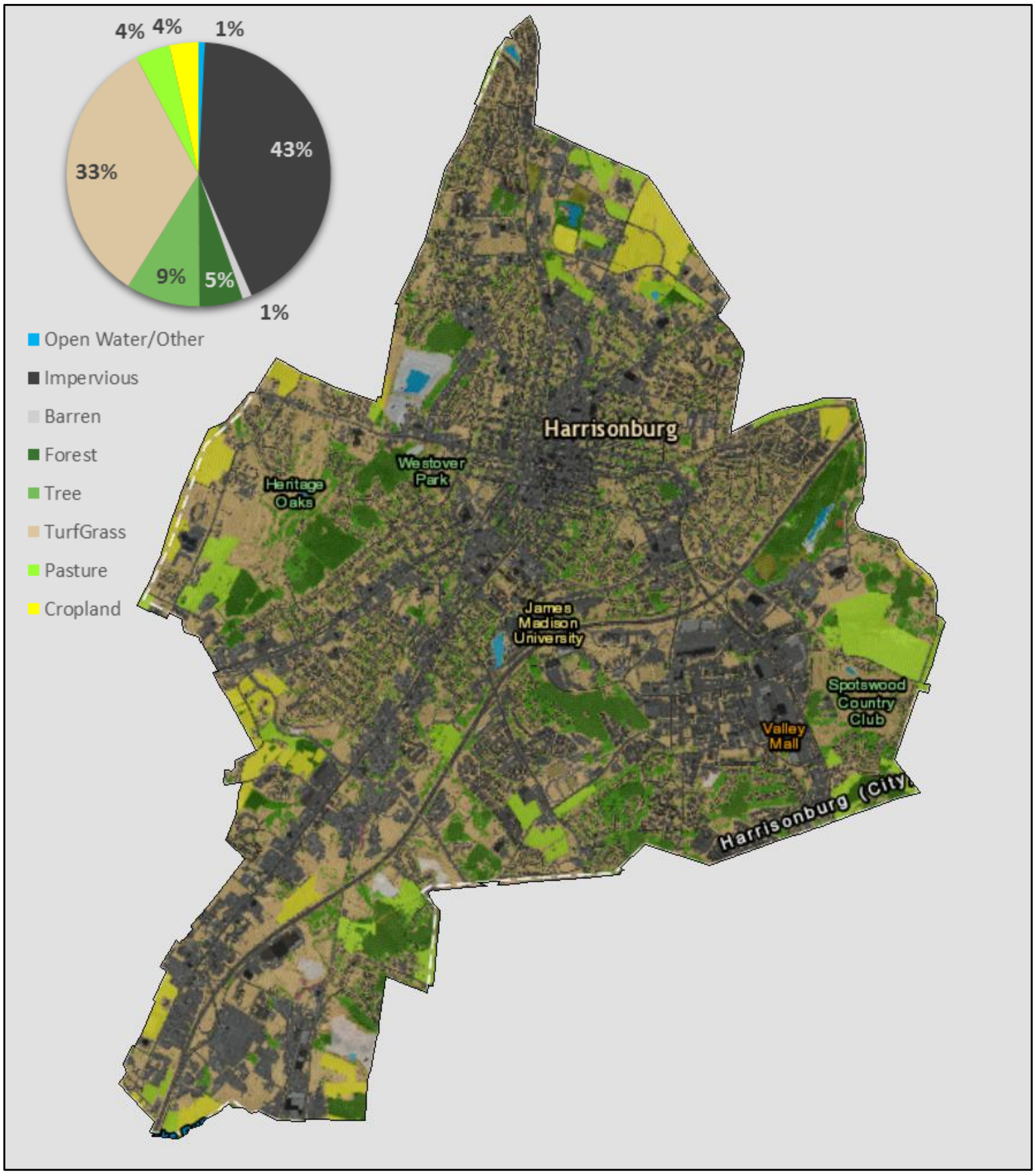


*Figure 8. Land cover for Harrisonburg.*
*%ISA estimate of 43% (VSLCD).*

Impervious surface is not the only cover type that determines stormwater runoff. An understanding of the influence of other land cover types, such as forest cover and open water, may also be integrated into future permit requirements (Jaime Bauer, phone call with Brandon Wheeler, May 9, 2016). For more on stormwater management, see section 1.2.

In 2018, DEQ will next update its Nonpoint Source Pollution Assessment and Prioritization, in which the VSLCD will replace the previously used NLCD (Karl Huber, e-mail to author, April 14, 2016). DCR was the lead nonpoint source (NPS) agency until July 2013, when DEQ took over producing the assessments with their continued assistance. DEQ uses a simulation model to develop estimates of NPS loads of nitrogen, phosphorus, and sediment. These estimates are converted to a unit area load per pollutant per hydrologic unit, ranked by percentiles, and mapped. These rankings are combined with one or more biological assessments in order to provide a prioritization model to guide decisions when applying NPS pollution control measures with limited resources. Among these resources are the Soil and Water Conservation Districts (SWCDs), which manage conservation programs and deliver free conservation services that aim to conserve soil resources, prevent soil erosion, prevent floods, and manage water resources. The VSLCD will aid the SWCDs in this work, as land cover type exerts influence over various soil and water concerns. Virginia's Nutrient Management Program (NMP) manages urban and agricultural nutrients that have the potential to contribute to NPS pollution and impair ground and surface waters. The NMP works with farmers directly to develop site-specific nutrient management plans. Data pertaining to land cover composition provided by the VSLCD can be subdivided by hydrologic unit and referred to when developing nutrient management plans. For more on nutrient management, see section 1.4.3.

## 2.3 Department of Conservation and Recreation

The Virginia DCR maintains many models and mapping efforts that will benefit from the inclusion of the VSCLD as an input. The Virginia Natural Heritage Program (NHP) works to protect the biodiversity of Virginia from rapid development by identifying and conserving vital ecosystems. In order to guide conservation decisions, the NHP utilizes the Virginia ConservationVision (ConVision), a suite of GIS tools and models developed and maintained by DCR. ConVision tools are used to map conservation priorities and guide decision-making related to green infrastructure planning. The tools provided by ConVision include a Natural Landscape Assessment, an Agricultural Model, a Cultural Model, a Forest Economics Model, a Recreation Model, a Development Vulnerability Model, and a Watershed Integrity Model. All of these tools and models have the opportunity to utilize the VSLCD as an additional land cover input, and three are described in further detail below.

The Virginia Natural Landscape Assessment (VaNLA) is a geospatial analysis tool for identifying, prioritizing, and linking natural lands across the state with the goal of combatting the development-driven fragmentation of Virginia's natural habitats (Figure 9). The VaNLA methodology involves identifying ecological cores, or large patches of natural, undeveloped land with at least 100 acres of interior cover that lies at least 100 meters from the edge of the patch. These ecological cores are assigned various attributes that are then used to prioritize them by ecological integrity. All cores in the highest ecological integrity categories are connected by landscape corridors. The 2017 update to VaNLA will likely integrate the VSLCD (Joseph Weber, e-mail to author, April 22, 2016). For more on habitat fragmentation, see section 1.4.1.

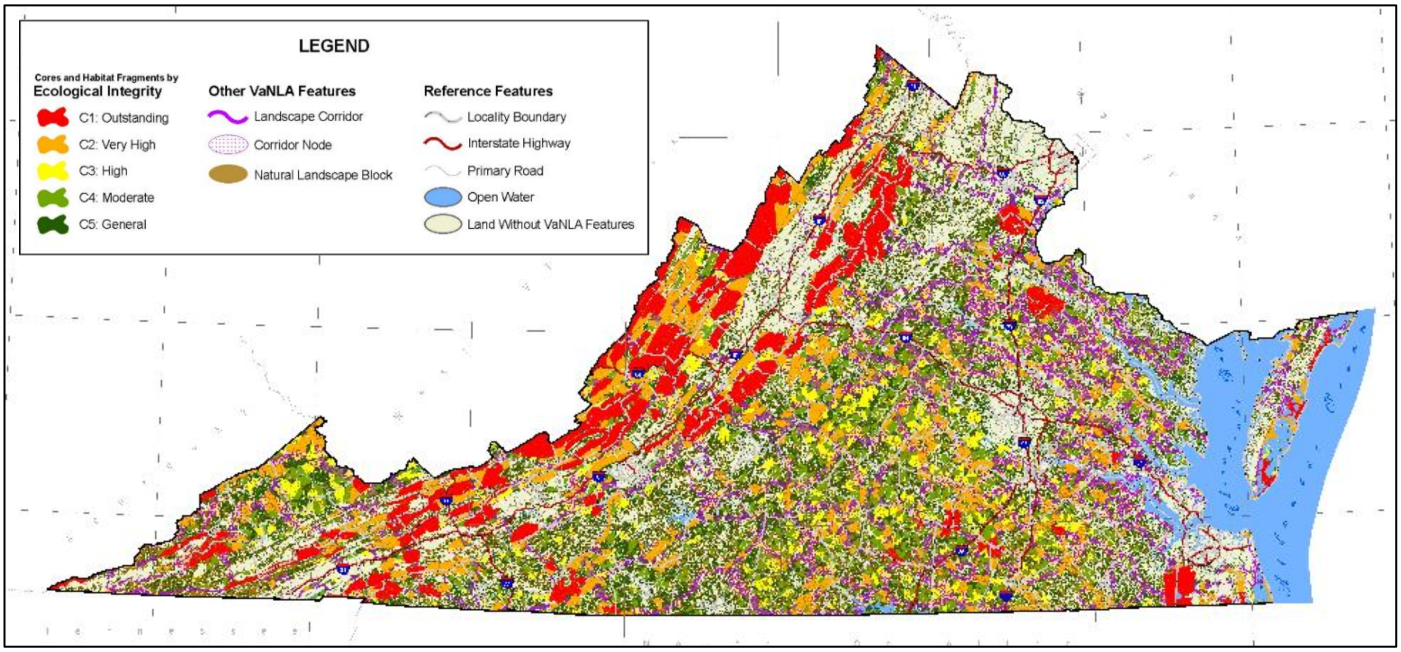


*Figure 9. Virginia Natural Landscape Assessment.*
*Adapted from DCR Natural Heritage.*

The Agricultural Model measures the relative suitability of Virginia's land for agricultural production in order to provide some focus for efforts to conserve optimal agricultural land. Agricultural suitability is based on soil suitability, current land cover, and travel time to consumers. This model could be updated to incorporate the VSLCD and thus achieve improved outputs.

The Development Vulnerability Model measures the relative risk of development of natural, rural, or open land and is consulted by the Land Conservation Foundation to rank grant applications for the purchase of permanent conservation easements. The model is based on travel times to urban areas and impervious growth hotspots and currently incorporates impervious data from the 2011 NLCD, but the VSLCD will provide more current, more reliable data for the forthcoming update to the model (Kirsten Hazler, e-mail to author, April 22, 2016). Furthermore, since the model was initially developed based on 2011 land cover data, the accuracy of the current model's predictions over the last several years will be tested using the VSLCD. For more on impervious surfaces, see section 1.1.

## 2.4 Department of Forestry

The Virginia Department of Forestry (DOF) relies on various GIS data, including land cover, to help manage, conserve, and restore the state's forest resources. Forests provide numerous economic and ecosystem services including timber production, biofuel resources, recreational space, wildlife habitat, air purification, groundwater filtration, erosion prevention, and carbon sequestration. When the 2011 NLCD was compared to the 2001 NLCD, it was found that forest cover experienced the largest net loss of over 3% or 16.5 million acres (EPA n.d.). This national trend necessitates the conservation and maintenance work undertaken by the DOF.

The VSLCD can support forest damage assessment via studying landscape change, which may occur as a result of wildfires, pests, invasive plants, natural disasters, climate change, harvesting, and landscape conversion (Jason A. Braunstein, e-mail to author, July 7, 2016). Once a change detection analysis has been conducted, the DOF can study where and why these changes in forest cover have occurred. The VSLCD specifically classifies harvested areas, which in themselves indicate a recent loss of forest and may even imply future land development. For example, Figure 10 shows land cover data for four counties in Virginia's Heartland Work

Area, where a total of over 64,000 acres (6% of total area) is classified by the VSLCD as harvested/disturbed forest. Sustainable timber harvesting is one of many DOF management goals in the Heart of Virginia.

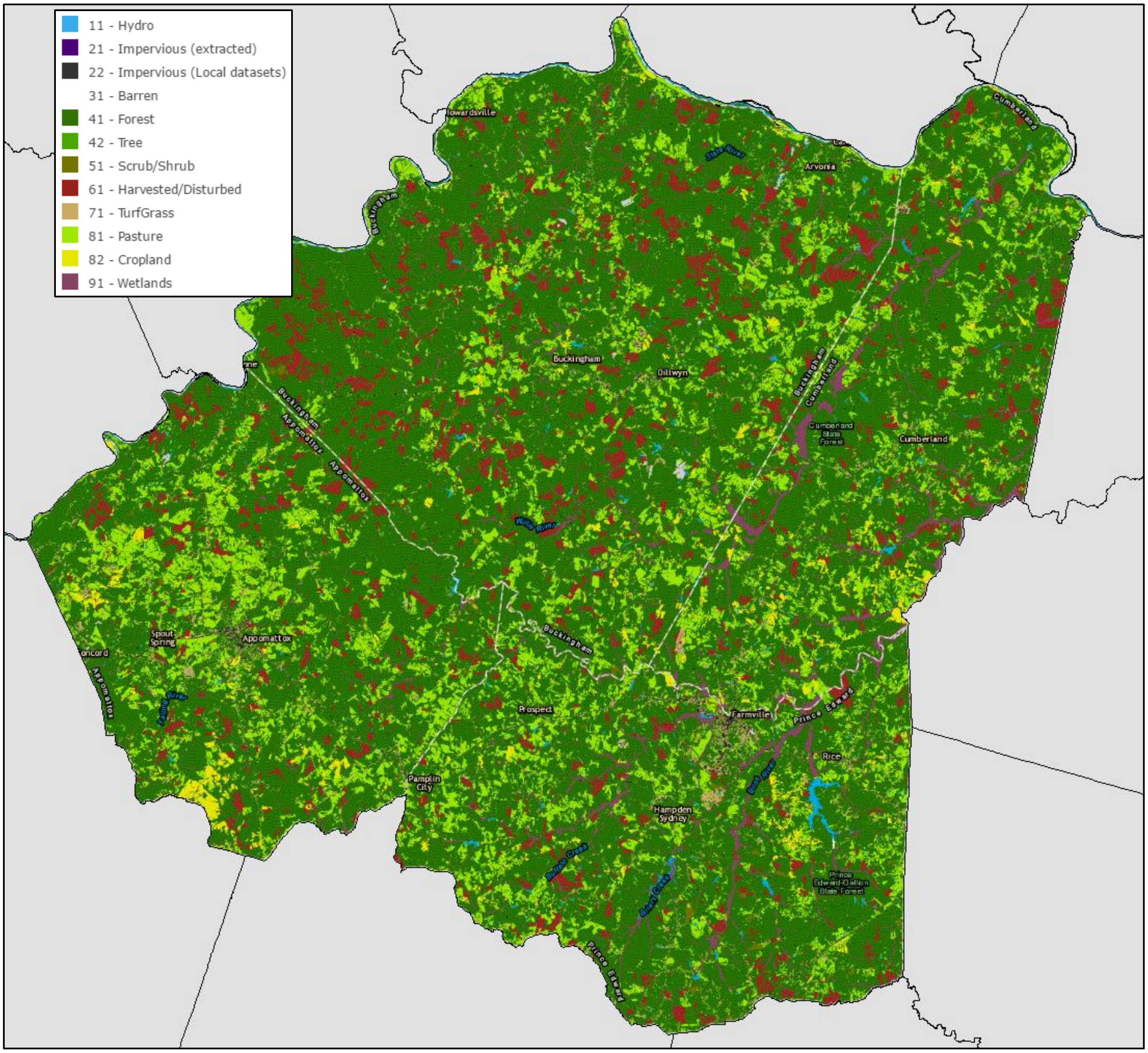


*Figure 10. Land cover for Appomattox, Buckingham, Cumberland, and Prince Edward Counties (VSLCD). Harvested/disturbed forest (red) covers 6% of the total area.*

By supplementing land cover data with a parcel dataset, foresters can identify landowners to whom technical services can be offered in the aftermath of a forest disturbance. The VSLCD may be a new input in the Forestland Conservation Value model, which pinpoints landowners whose property may be the ideal location for a conservation easement (Jason A. Braunstein, e-mail to author, July 7, 2016). Urban sprawl (see section 1.3.1) is another concern of the DOF; thus, the Forest Resource Assessment, which assesses the impact of suburban growth on forest resources, can be updated using the more current data provided by the VSLCD. In the interest of protecting water quality, riparian buffers (see section 1.4.2) can be evaluated, and forest operations that may be candidates for Best Management Practice (BMP) monitoring can be detected. Through all of these applications, the VSLCD can help the DOF protect Virginia's forests.

## 2.5 Non-Governmental Organizations

The efforts of non-governmental organizations (NGOs) with sufficient technical resources to conduct GIS analyses will be enhanced by the publicly available VSLCD. Just a few examples of NGOs that may benefit include the Chesapeake Bay Program, the Nature Conservancy, and the James River Association.

### 2.5.1 Chesapeake Bay Program

The CBP is a regional partnership focusing on the protection and restoration of the Chesapeake Bay, with participation from Maryland, Pennsylvania, Virginia, the District of Columbia, the EPA, and the Chesapeake Bay Commission. The CBP's work heavily involves geospatial modeling and analysis. Their largest project, the Resource Lands Assessment, consists of six separate GIS-derived models which have the purpose of determining the value of resource lands in the Chesapeake Bay watershed. The six models consist of the Ecological Network Model, the Water Quality Protection Model, the Forest Economics Model, the Prime Farmland Model, the Cultural Assessment Model, and the Vulnerability Model. For many of these simulations, land cover data are a critical input. For example, the Water Quality Protection Model requires estimates of forested area and %ISA. The Ecological Network Model currently utilizes the NLCD for land cover information related to identifying forest patches. The Prime Farmland Model uses 2000 land cover data to identify and quantify agricultural areas. These models, shown in Figure 11, are just a few examples of models that can be updated using the VSLCD.

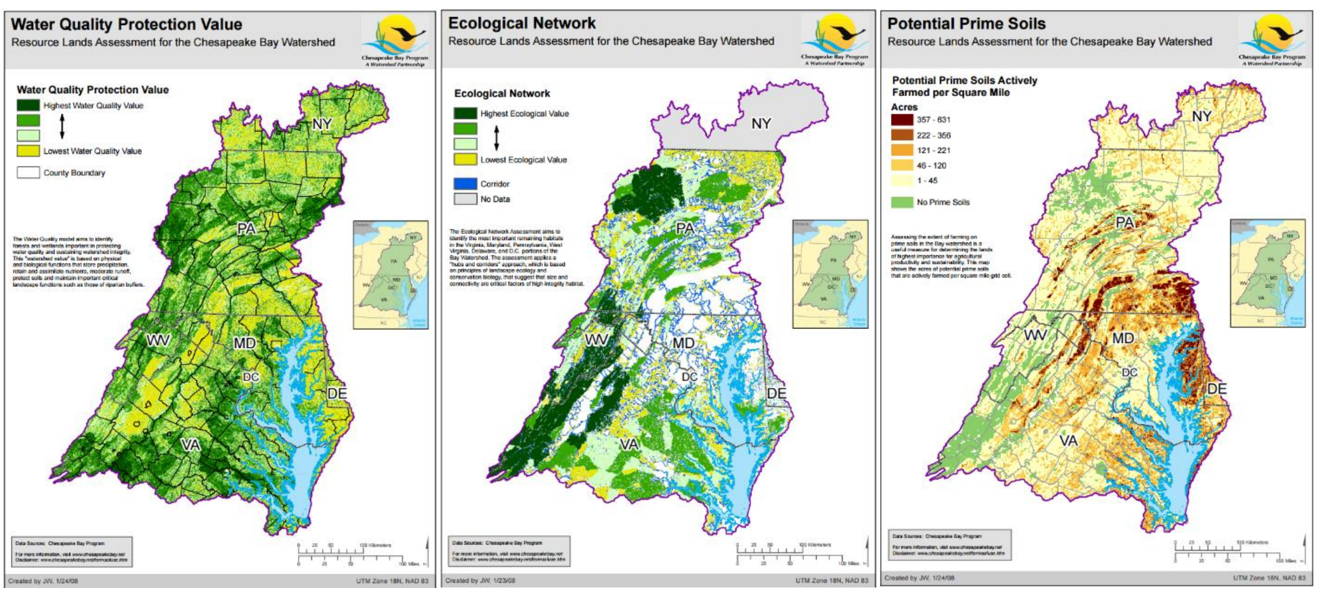


*Figure 11. Water Quality Protection Model, Ecological Network Model, Prime Farmland Model. From Chesapeake Bay Program.*

The CBP also develops and maintains a Watershed Model, currently in Phase 5.3, that integrates land cover along with a plethora of other data in order to simulate river flows and nutrient and sediment loading in the Chesapeake Bay under various scenarios. The reduction of nutrient and sediment loading is vital to the long-term health of the Bay. Nutrient loading leads to toxic algae blooms and hypoxic bottom waters, which are detrimental for all aquatic life. Sediment loading causes turbidity, which disturbs algae and submerged aquatic vegetation by impeding light penetration. If the sediment contains harmful contaminants, these may biologically accumulate in filter feeders. The Watershed Model's simulations provide insight for watershed management efforts that strive to protect water quality and restore the living resources of the Bay by meeting watershed-wide caps on nitrogen and phosphorus along with more localized caps on sediment. Management efforts are assessed by their ability to achieve criteria water quality targets, which are measured in terms of dissolved oxygen, chlorophyll, and clarity.

In 2017, Phase 6 of the model will be released with the VSLCD serving as the land cover input for Virginia. This update will enhance the quality of the land use/land cover inputs and develop BMP data to better align with on-the-ground conditions. In return, the updated model will support more accurate forecasting of future development trends and patterns and become more useful as a planning instrument leading to the full implementation deadline in 2025. Before this update, Virginia has been reporting BMP implementation aggregated to larger scales to avoid model conflicts with incorrect land use classification. The downside of this is that localities may have seen model reductions or had their levels diluted by the activity in neighboring localities. With improvements to the model and the new calibration, Virginia has the opportunity to reset and to report BMP implementation at the locality scale, or possibly finer, where each locality's efforts would be individually reflected, which could reveal greater load reductions in the model results.

### 2.5.2 The Nature Conservancy

In Virginia, the high-level goals of the The Nature Conservancy (TNC) include conserving forests and woodlands, protecting rivers and the Chesapeake Bay, sustaining the ocean and coastal zones, and combatting climate change. Using land acquisition and conservation easements, TNC collaborates with landowners to conserve and protect private and public land to achieve these larger goals. Estimates of total forest, riparian forest, and %ISA will be extracted from the VSLCD and utilized in conservation prioritization analysis, which is based on threats to and conditions in the watershed (Chris Bruce, e-mail to author, April 19, 2016). TNC recently expanded its Coastal Resilience tool for risk management to Virginia's Eastern Shore, which is under threat from sea level rise and intensifying storms. This will provide Eastern Shore communities with a powerful decision-making tool for assessing risk to both property and natural resources as well as identifying risk management solutions. The model incorporates impervious surface data derived from the NLCD and will likely be updated using the more accurate one-meter data (Chris Bruce, e-mail to author, April 19, 2016). TNC also participates in stream and wetland restoration and will use the VSLCD to model nutrient reduction benefits (see section 1.4.3) of restored sites (Chris Bruce, e-mail to author, April 19, 2016).

### 2.5.3 James River Association

The James River Association's (JRA) Watershed Restoration program has many aims: 1) to manage stormwater runoff and restore ecosystems by integrating green infrastructure into the regional landscape, 2) to identify and remove invasive plant species, especially in riparian areas, and 3) to restore and enhance riparian buffers. All of these projects fall under the overarching goal of improving the health of the James River. High-resolution land cover data are critical in both green infrastructure planning (see section 1.4.1) and riparian buffer analysis (see section 1.4.2). JRA has considered using Chesapeake Conservancy's one-meter resolution land cover dataset of the James River watershed to assist in identifying ideal locations for riparian buffer plantings and cattle exclusion fencing but has not found it to be an adequate replacement for on-the-ground research (Amber Ellis, e-mail to author, August 1, 2016). However, riparian buffer analysis is included in JRA's ten-year plan, and the development of a riparian buffer analysis from the VSLCD is being reviewed as a potential project under the Water Quality Improvement Fund. Compared to the Chesapeake Conservancy data, the VSLCD has similar resolution and accuracy but more detailed classifications (Figure 12), which renders it more suitable for many applications.

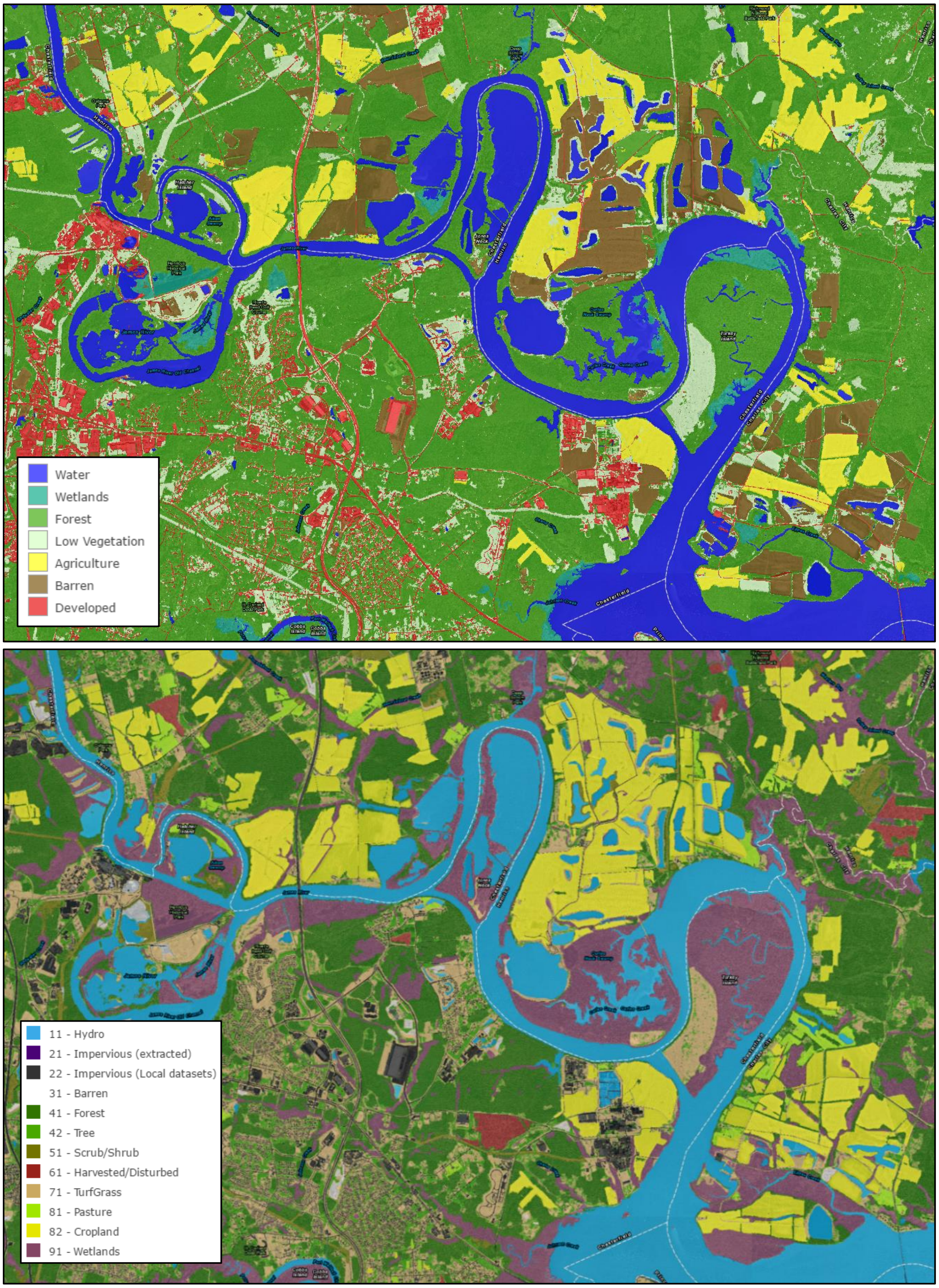


*Figure 12. Chesapeake Conservancy High Resolution Land Cover (top), VSLCD (bottom).*

# 3. Local Modeling Inputs

Knowledge of the present distribution and area of different land cover is needed by planners and local governmental officials to improve land use policy, project future transportation and utility demand, identify areas vulnerable to future development, and implement effective plans for regional development (Anderson, et al. 1976). A number of Virginia localities are already leveraging land cover datasets to accomplish some of these goals.

## 3.1 Albemarle County

### 3.1.1 Chesapeake Bay TMDL Action Plan

The goal of the Chesapeake Bay TMDL, established by the EPA under the Clean Water Act, is to restore clean water to the Chesapeake Bay and the streams and rivers that feed it. To meet federal water quality standards, the TMDL requires reductions in three major water pollutants: nitrogen, phosphorus, and sediment. Control measures that ensure full restoration of the Bay are expected to be in place by 2025. Phase I Watershed Implementation Plans (WIPs) specify how and when jurisdictions are required to meet the new standards while Phases II and III strengthen the original strategies and provide additional strategies to ensure that each reduction benchmark is met. Pollutant reductions will be met in increments divided across three five-year VPDES permit cycles between 2013 and 2028 by installing and retrofitting BMPs, completing capital improvement projects, implementing nutrient management plans, connecting septic systems to sanitary sewers, and street sweeping. Directed by DEQ, Albemarle County, located in the James River watershed, developed an action plan to achieve the reductions allocated to urban areas under the first VPDES permit.

During the development of this action plan, an MS4 regulated area needed to be established to delineate the drainage area and all conveyances served by the MS4 that fall within the County's jurisdiction while excluding forests, agricultural lands, wetlands, and open water. To accomplish this, a high-resolution land cover dataset of the Rivanna watershed based on 2009 imagery was used to identify forested areas and water bodies, which do not need to be regulated because they do not contribute to loading. The fine resolution of the data allowed differentiation between true forest and small clusters of trees that do not function as true forest. This was accomplished by creating a 25-foot buffer around all impervious surfaces as well as establishing a minimum contiguous area threshold of 0.5 acres. Only forested areas outside of the 25-foot buffer that were larger than 0.5 acres were classified as true forest. The exclusion of agricultural areas and wetlands was not possible at the time due to a lack of adequate data (Stavros Calos, e-mail to author, July 21, 2016). All other land cover types were categorized as either pervious or impervious and total acreages of each were calculated. The VSLCD (Figure 13) classifies forested areas into separate "tree" and "forest" categories and offers reliable classification of agricultural lands and open water. The VSLCD also includes a wetland class derived from the NWI, which may not be adequate for this application. The VSLCD-derived land cover breakdown for Albemarle County, excluding Charlottesville, can be found in

Table 1 below.

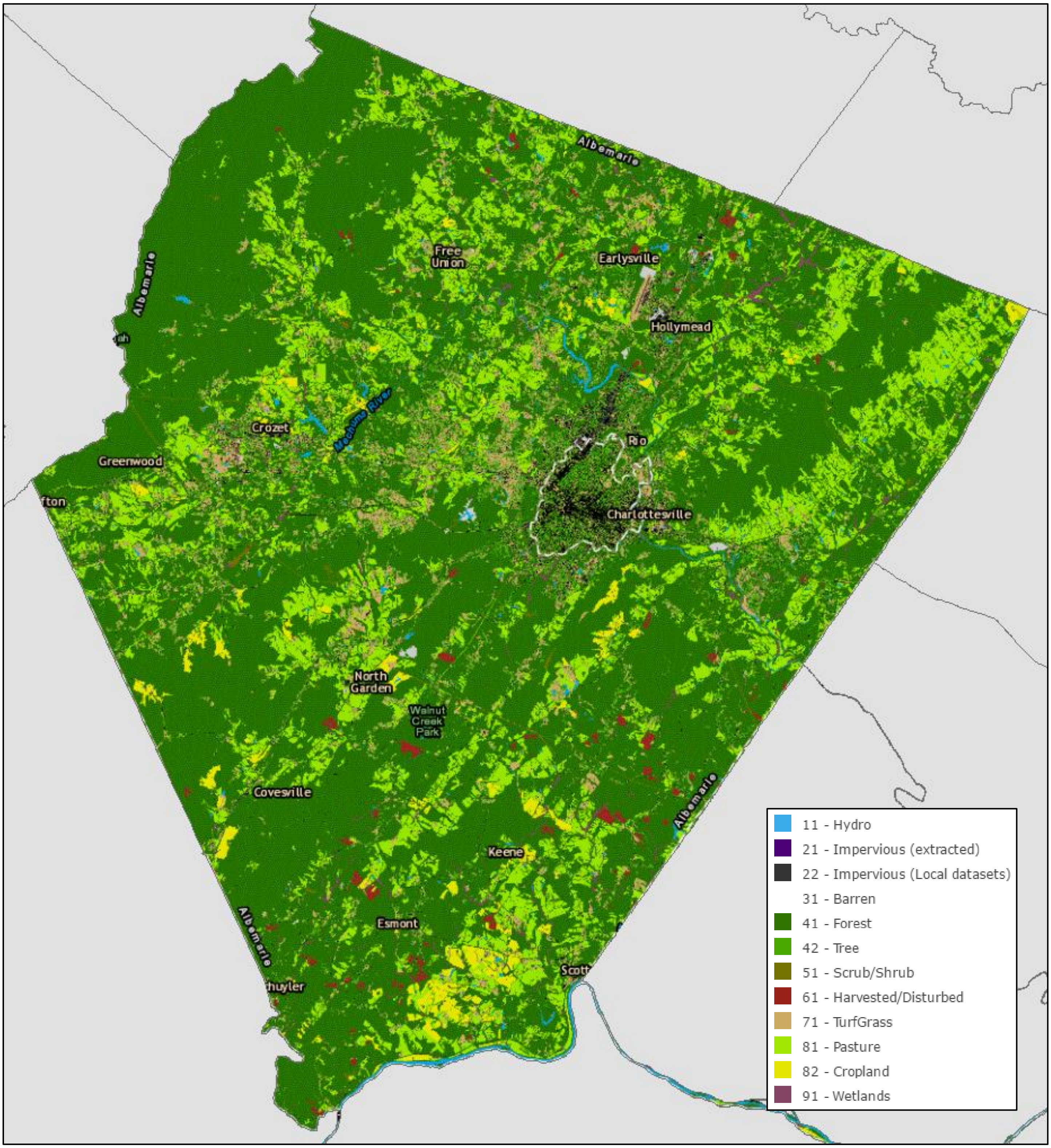


*Figure 13. Land cover for Albemarle County and City of Charlottesville (VSLCD).*

*Table 1. Land cover classification breakdown by acreage and percentage for Albemarle County (VSLCD).*

| Classification | Acreage | % of total |
|---|---|---|
| **Open water** | 2,264 | 0.49% |
| **Impervious** | 12,153 | 2.62% |
| **Barren** | 737 | 0.16% |
| **Forest** | 305,336 | 65.94% |
| **Tree** | 26,701 | 5.77% |
| **Shrub/Scrub** | 1,520 | 0.33% |
| **Harvested/Disturbed** | 2,677 | 0.58% |
| **Turf grass** | 26,573 | 5.74% |
| **Pasture** | 73,972 | 15.98% |
| **Cropland** | 8,046 | 1.74% |
| **NWI/Other** | 3,065 | 0.66% |
| **Total** | 463,043 | 100.00% |

For the purposes of determining the actual load reductions that would be required to meet the allocations, pollution sources were categorized into existing, new, and grandfathered sources. Existing sources were based on 2009 land cover, new sources were based on changes to land cover occurring between 2009 and 2014, and grandfathered sources were based on changes occurring after 2014 but would be permitted under old MS4 requirements. New sources were identified by comparing 2014 planimetric data to 2009 land cover and by analyzing the county database for approved site plans, subdivisions, and other activities. This could be accomplished more directly by conducting a change detection analysis using two temporally disparate land cover datasets.

The second VPDES permit cycle begins in 2018, and new action plans will likely be required shortly thereafter. If DEQ requires a similar planning process calling for land cover mapping, the VSLCD will almost certainly be the standard land cover input for localities statewide (Stavros Calos, e-mail to author, July 21, 2016). This standardization will not only benefit the localities themselves, but also DEQ, on whom the onus lies to verify land cover estimates submitted with each action plan (see section 2.2).

### 3.1.2 Rivanna River Basin Stream Health Study

Healthy streams that support biodiversity boast better water quality and can provide recreational space and drinking water to residents. Stream health declines predictably with increasing intensity of land development; this formed the basis for the Rivanna River Basin stream health study. With the goal of studying the relationship between land use, stream habitat, and stream biology, StreamWatch collected stream life and habitat data at 51 sites across the basin and then utilized the 2010 Rivanna Watershed land cover dataset (RWLCD) to develop a stream condition model (Figure 14).

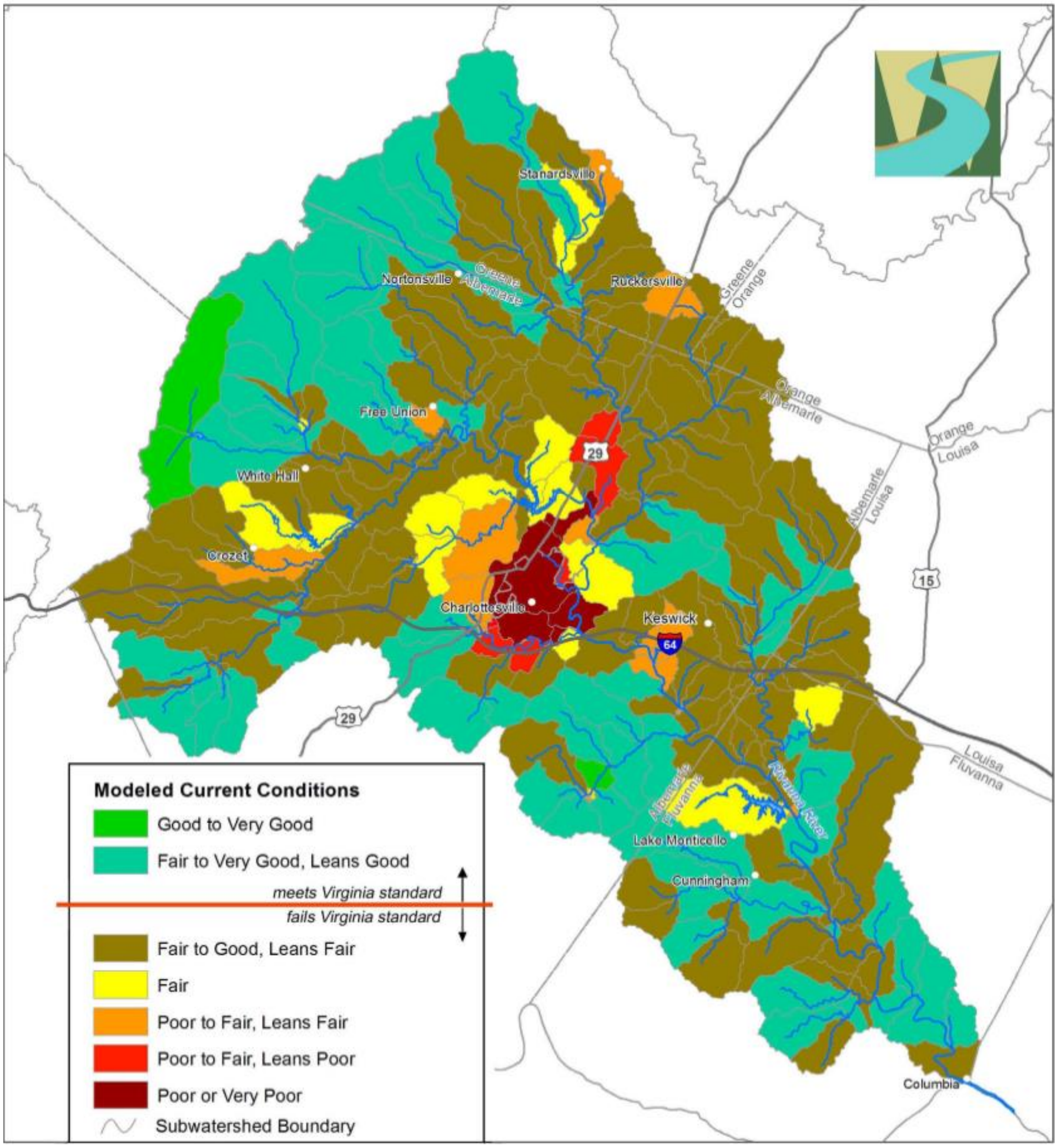


*Figure 14. Modeled stream conditions in the Rivanna River Basin. (Murphy 2011).*

Biotic integrity was assessed at each site based on an eight-metric index that reflects various attributes of the benthic macroinvertebrate community such as diversity and stress tolerance. It was found that percent forested and percent impervious cover correlated strongly with stream health, so these parameters formed the basis for the model, which is about 85% reliable at predicting biological condition.

The stream health model estimates that 70% of stream systems in the basin fail the state regulatory standards while 6% of stream systems are in poor health, mostly in urban areas. It was found that streams tend to breach state regulatory thresholds as drainage areas reach 3% ISA, which is significantly lower than the 20% ISA threshold found by other models (Murphy 2011). The land cover configuration associated with this 3% threshold is characteristic of exurban development, the most common development pattern among the subwatersheds of the Rivanna River Basin.

Land cover changes such as development and deforestation contribute to rapid stream degradation; therefore, the model can be used to predict the effects of projected population growth and exurban development on stream health. Based on the 2010 census, the non-urban population is expected to increase by 50% by 2030. When this scenario was tested using the stream health model, it was found that increasing average %ISA per subwatershed from 2.6% to 3.4% would cause the number of stream systems meeting state regulatory standards to decrease by one-third (Murphy 2011). The model can also be used in restoration planning to estimate the percent forest and impervious cover required to achieve a target level of stream health. It was also found that riparian zone conditions correlated with stream health, and it was concluded that the restoration of riparian zones can help to mitigate the impacts of land disturbance on stream health (Murphy 2011). The availability of the VSLCD (Figure 13) makes this type of study possible for localities that do not have the resources to develop their own land cover data.

### 3.1.3 Buffer Analysis and Change Detection

Albemarle is conducting a buffer analysis to determine percentages of forest, open space, and impervious cover within RPAs (Greg Harper, e-mail to author, July 21, 2016). The analysis is being conducted using both the RWLCD and the VSLCD. The two datasets are compared in Figure 15 below. As the RWLCD is based on 2009 imagery, and the VSLCD is based on 2013 imagery, some differences in buffer composition between the two years may be found, but major differences are not necessarily expected (John Murphy, e-mail to author, July 21, 2016). Change detection between the RWLCD and the VSLCD can also be conducted at the county-, zoning district-, or watershed-level (David Hannah, e-mail to author, July 28, 2016). At local scales, land cover changes become apparent. In the example below (Figure 16), it is clear that land development has occurred west of Charlottesville. Several construction sites, classified as bare land in the RWLCD, have been converted to turf and impervious in the VSLCD, in the forms of two residential areas and a hospital.

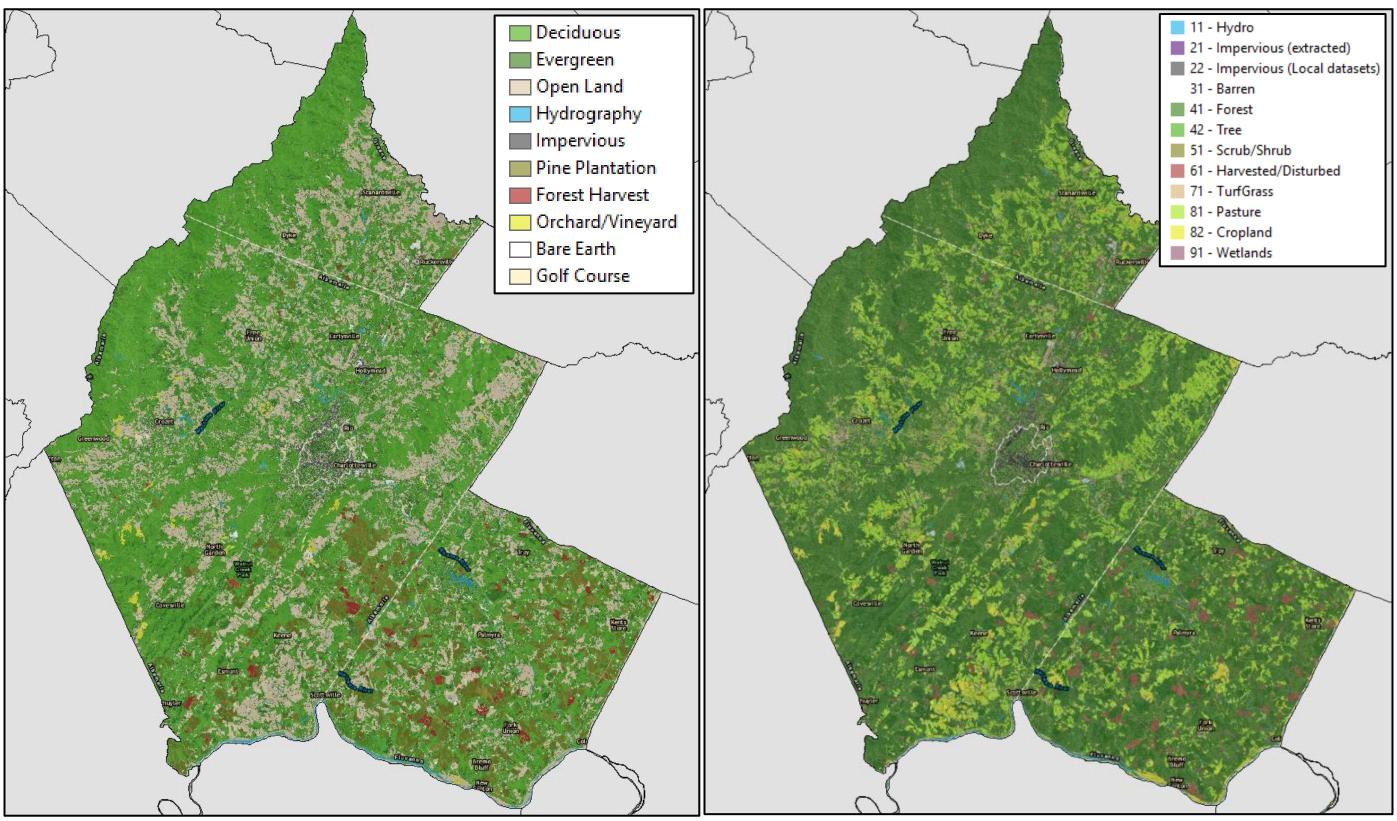


*Figure 15. Land cover for Albemarle, Fluvanna, and Greene Counties.*
*RWLCD (left), VSLCD (right).*

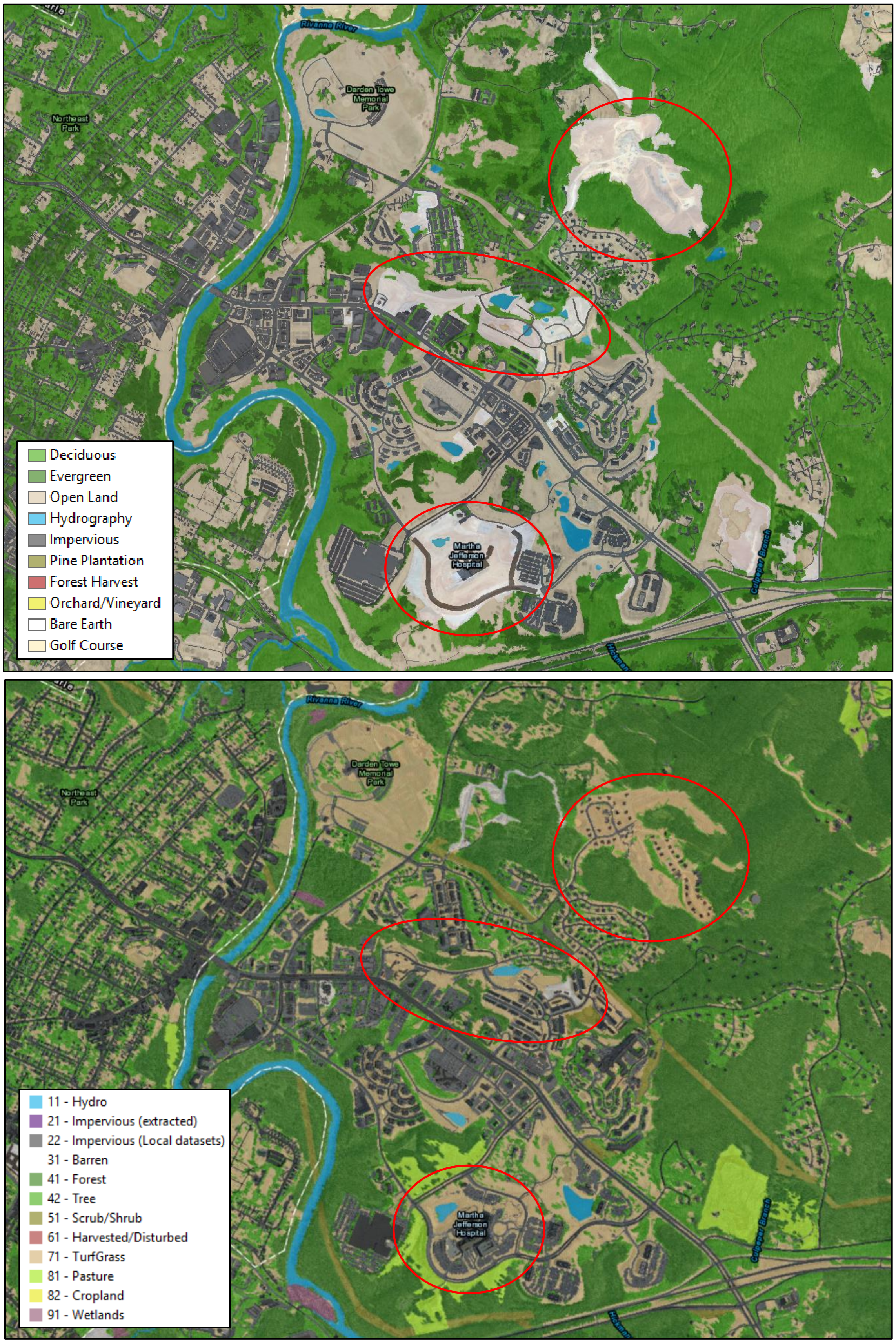


*Figure 16. Land cover change west of Charlottesville between 2009 and 2013. RWLCD (top), VSLCD (bottom).*

### 3.2 Accomack County Blue/Green Infrastructure Study

Accomack County's Comprehensive Plan identifies the conservation of the county's natural resources among its major goals. With funding provided by the Virginia CZM Program, Accomack and the Green Infrastructure Center conducted a study from 2009-2010 that sought to identify and develop asset protection strategies for blue/green infrastructure assets, such as wetlands, riparian corridors, ideal farmland, ideal timberland, and key wildlife habitat. Green infrastructure planning (see section 1.4.1) uses natural resources and working lands to achieve a variety of goals: mitigating habitat fragmentation, ensuring water and air quality, supporting historic and cultural resources, improving residents' quality of life, and sustaining the local economy. Green infrastructure planning connects ecological cores via a network of corridors to allow free movement of people, plants, and wildlife across the landscape. Blue infrastructure supports fisheries, tourism, and water recreation. There is a strong relationship between the health of blue and green infrastructure, as green infrastructure serves to maintain healthy streams, which in turn support healthy estuaries.

Information gathering for the study occurred in three phases: data collection, asset mapping, and risk and opportunity assessment. Data was collected from Natural Heritage's VaNLA and Priority Conservation Areas (PCA) as well as from scientific journals, government agency studies, NGO reports, and academic research. The second phase involved the development of a set of green infrastructure asset maps that follow various themes. Thirdly, the risk assessment identified green infrastructure that is at risk from development or other changes in land use while the opportunity assessment evaluated the asset and risk maps to identify conservation, enhancement, and restoration opportunities. Using data from VaNLA and PCA, a Green Infrastructure Base Map (Figure 17) was created to show connected, intact landscape features at least 100 acres in size with the highest ecological value along with the landscape features at least 1,000 feet wide that connect them. This map elucidated that Accomack possesses a vast green infrastructure network that provides numerous benefits; however, it was also found that many corridors are not of sufficient width, fragmentation of the landscape is one of the most significant threats to the county's assets, and stormwater management should be a focus of green infrastructure planning.

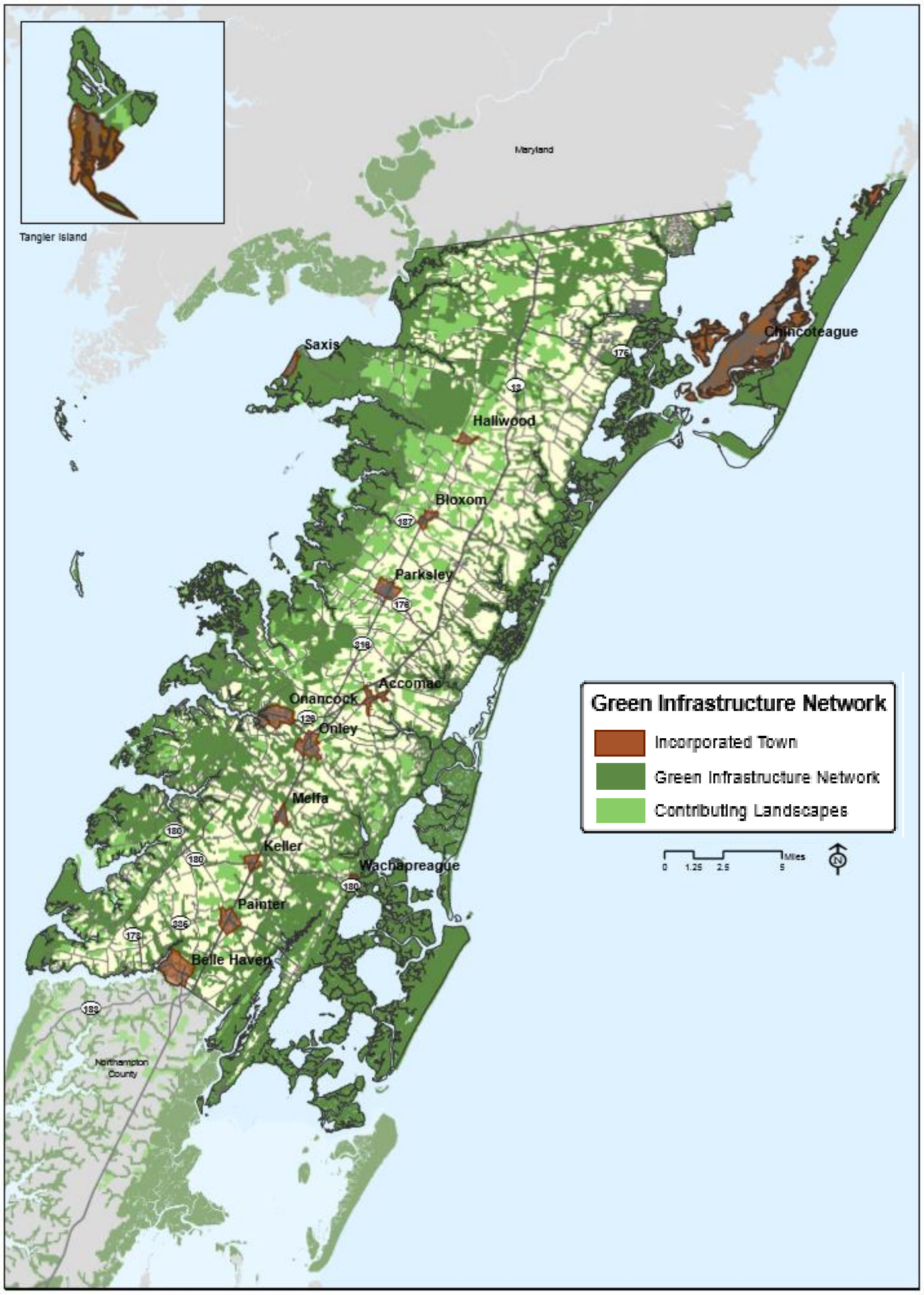


*Figure 17. Accomack Green Infrastructure Base Map.*
*Adapted from Accomack County Blue/Green Infrastructure Study.*

Five theme maps were developed as overlays to the base map: Habitat and Wildlife Conservation, Water Quality, Working Lands: Agriculture, Forestry and Working Waters, Nature-Based Recreation, and Culture and Heritage. These overlays provide a comprehensive view of how green infrastructure relates to other aspects of the landscape. The Habitat and Wildlife Conservation Map delineates priority habitat and wildlife assets such as RPAs (see section 1.4.2) and conservation easements. This map aims to target conservation activities toward vulnerable areas. The Water Quality Map identifies water resources, forest cover, forested wildlife corridors, watershed boundaries, and community wells. This map provides evidence that many streams are lacking a sufficient buffer, many headwaters exist in developed areas, community wells are often clustered around developed areas, and tidal wetlands along the coast provide an important habitat. The three Working Lands Maps, Agriculture, Forestry, and Working Waters, show the locations of prime agricultural soils, forest cover and large forested parcels, and fishery management areas and public oyster grounds, respectively. Prime agricultural soils that are in danger of development are a perfect focal point for conservation. Large forest parcels are better suited to timber management and to supporting wildlife, while small forest parcels fragment and degrade the forest habitat. The Nature-Based Recreation Map shows locations of recreational resources such as trails, rivers, and parks. These tend to be located in conjunction with green infrastructure. Finally, the Culture and Heritage Map shows churches and cemeteries, Historic Districts, and Historic Register Sites. Potential Historic Districts are also identified, as well as potential scenic roads and a bicycle route plan.

As a product of the opportunity assessment, several opportunity maps were developed. The Future Land Use Map compares the county's future land use plans to the green infrastructure network. Accomack planned for future development to occur around incorporated towns in order to conserve large areas for rural use. Clustering development in this manner also protects the green infrastructure network. The Groundwater Recharge and Wellhead Protection Map identifies risks and opportunities related to water quality. Community wells are shown with a 1000-foot protection buffer to reflect the requirement set by the Commonwealth of Virginia's Wellhead Protection Plan. The groundwater recharge area that runs along the center of the county is also shown as well as tidal wetlands and watershed boundaries. Green infrastructure filters runoff, which makes it a critical tool in water quality protection.

All these maps were consulted during the prioritization of conservation strategies in the final phase of the study. The strategies include riparian rungs to enhance east-west connectivity, coastal corridors to promote coastal habitat connectivity, and a recharge window to protect the groundwater recharge zone via best management practices. Any organization or locality that wishes to conduct a similar study can use the VSLCD (Figure 18) as a starting point for developing green infrastructure maps that can inform a comprehensive plan, zoning maps, and conservation strategies.

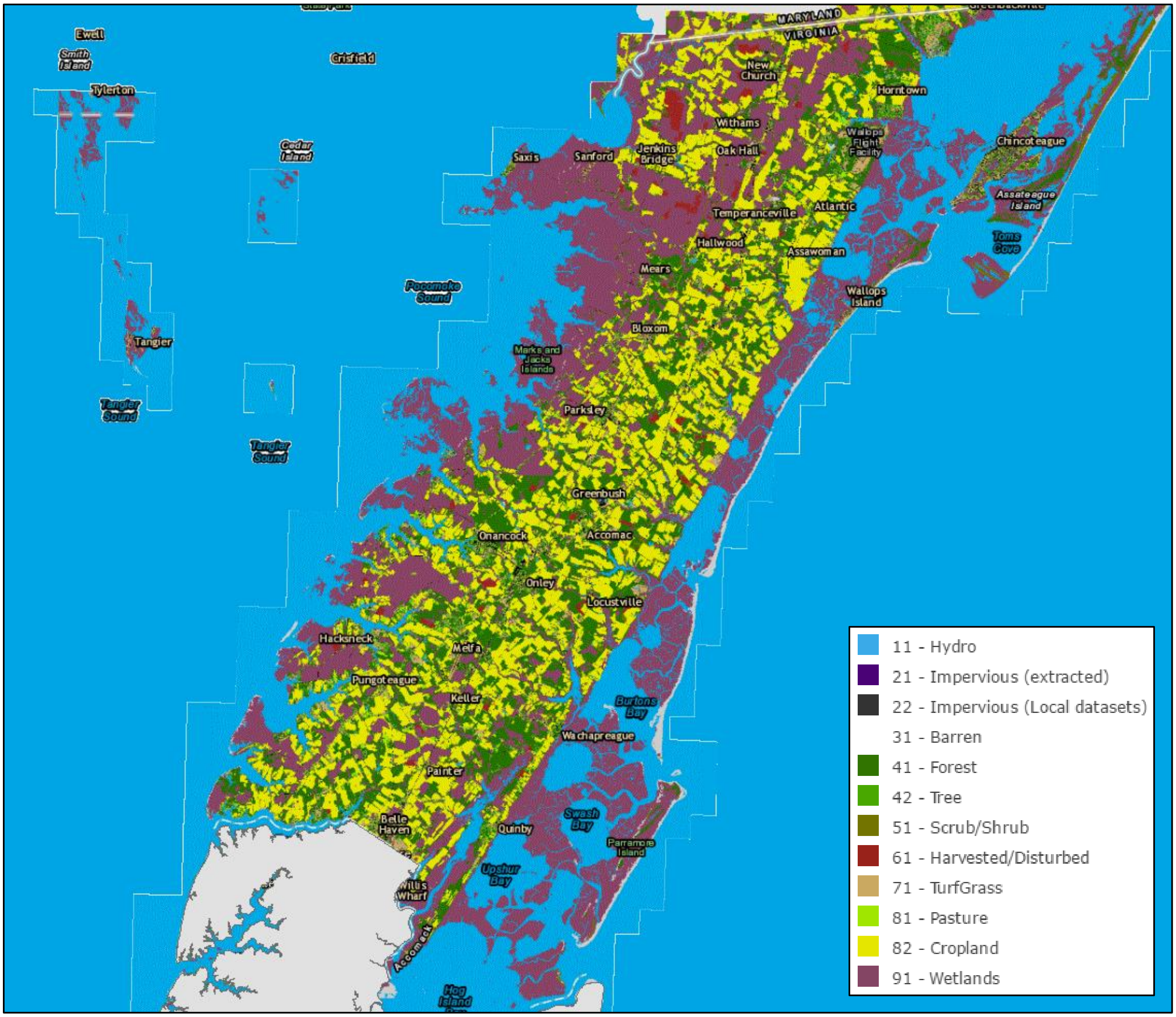


*Figure 18. Land cover for Accomack County (VSLCD).*

## 3.3 Hampton Roads Conservation Corridor Study

The Hampton Roads Planning District Commission (HRPDC) conducted a Conservation Corridor Study in 2006 to identify critical natural resources in the region. This green infrastructure-based approach aims to protect a linked network of conservation corridors in the face of continuing urban development. Such a corridor system can help Hampton Roads meet a variety of conservation, open space, regulatory compliance and other planning goals. In order to focus conservation efforts, a suitability model was developed using weighted overlay analysis to identify areas where a conservation corridor would be most effective in terms of protecting natural habitat and water quality. The datasets utilized in this model include the National Wetlands Inventory (NWI), the NLCD, VaNLA ecological cores, and riparian corridors. The data layer that was derived from the NWI merely shows the presence or absence of wetlands and was assigned a yes/no suitability ranking. The 21 NLCD classes were conflated to just six suitability categories and ranked from low to high: high intensity development/open water, low intensity development, agriculture, forest/open space, sand/beaches, and wetlands. VaNLA cores within the region were identified and ranked by ecological significance based on factors such as species diversity and stream quality. Riparian corridors were derived by buffering the 2002 VBMP hydrology dataset at

100, 200, 300, 400, and 500 feet, and these buffers were also ranked by suitability. The suitability ranks of each input dataset were weighted equally and combined to form a Conservation Corridor Suitability Map. Refinements to the model integrate stakeholder input by assigning relative weights to each input layer rather than weighting them equally. For example, land cover can be given a relative weight of 10.4 while riparian areas can be given a weight of 1.0. The final Opportunities for Connectivity map (Figure 19) emphasizes where opportunities exist to integrate green infrastructure into the landscape in order to enhance forest connectivity to protect natural habitat and water quality.

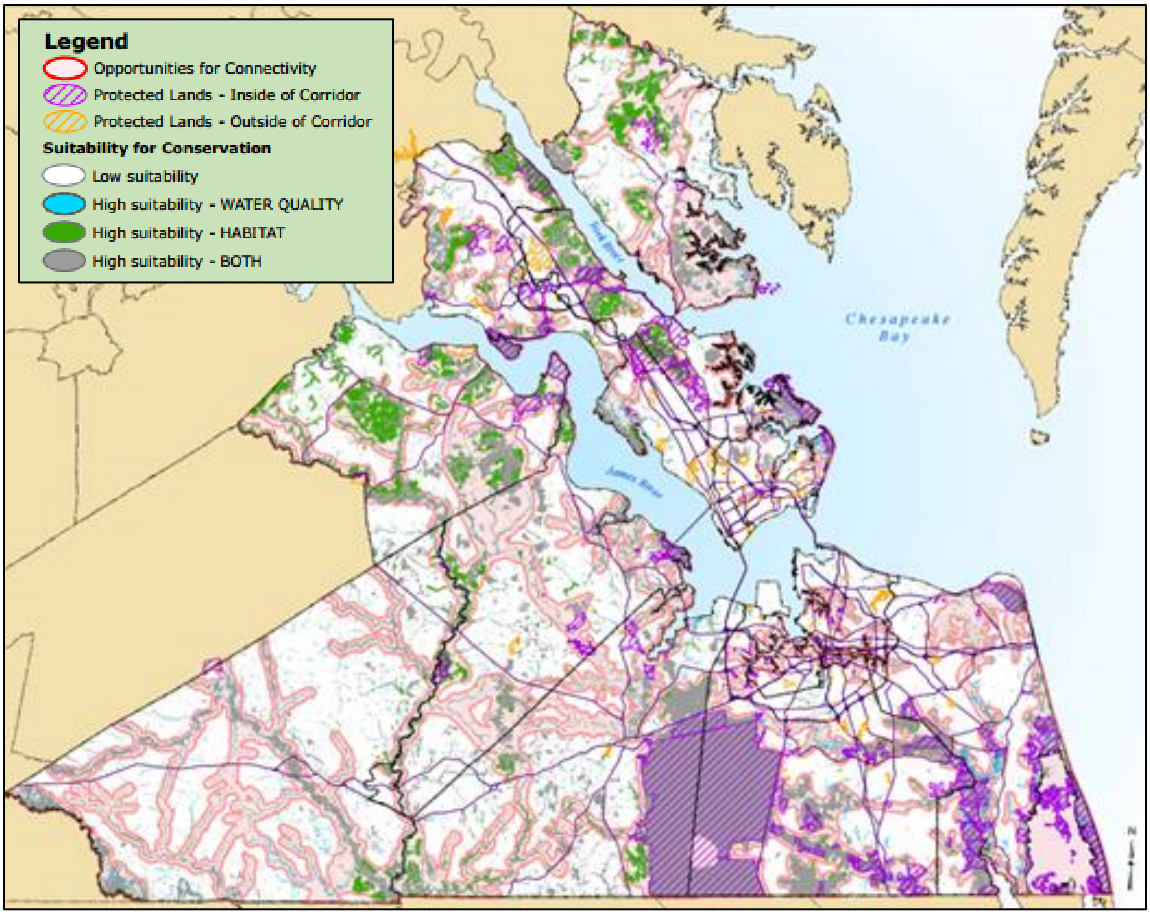


*Figure 19. Opportunities for Connectivity Map.*
*Adapted from the Hampton Roads Conservation Corridor Study.*

A future study like this, especially one at a more localized level, could be improved by substitution of the VSLCD (Figure 20) as a higher-resolution and more up-to-date land cover input as well as in the derivation of riparian corridors. For more on green infrastructure planning and riparian corridors, see sections 1.4.1 and 1.4.2, respectively.

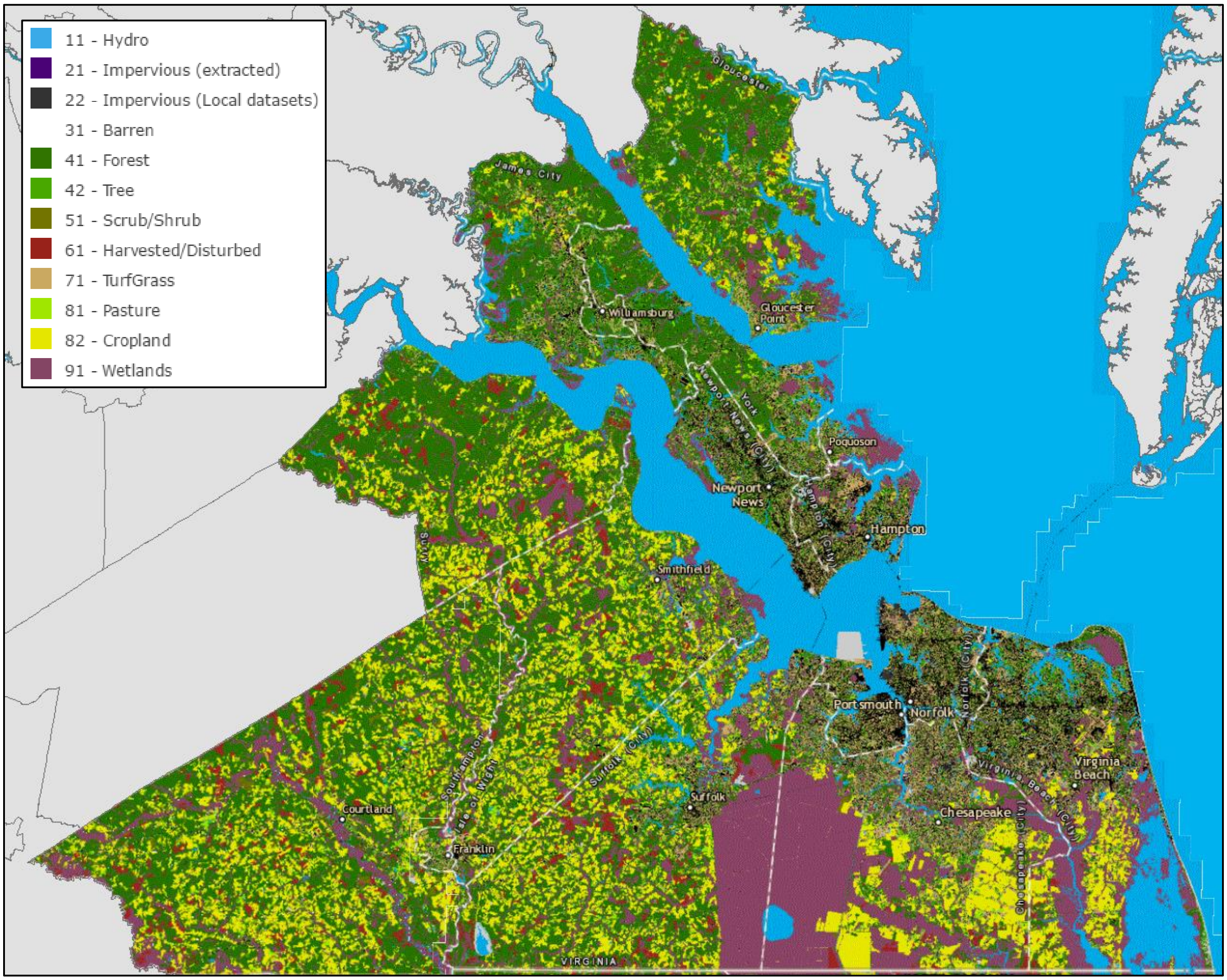


*Figure 20. Land cover for Hampton Roads Region (VSLCD).*

## 3.4 Norfolk Flood Risk Management Study

Through completion of the two-year North Atlantic Coast Comprehensive Study, the U.S. Army Corps of Engineers (USACE) identified the City of Norfolk as one of nine high-risk areas vulnerable to storm-induced flooding and sea level rise. Surrounded by water on three sides with 144 miles of shoreline, Norfolk (Figure 21) is a densely populated and low-lying urban area; therefore, flooding is frequent and widespread. Large flood events cause property and infrastructure damage while smaller, more frequent events affect the local economy and hinder emergency services. Much of the local industry relies on the city's ports and shipyards, which, due to their location, are most susceptible to flood damage. Evacuation routes are limited, thus further endangering Norfolk's large population. When the city was developed in the late 19th and early 20th centuries, it was standard practice to fill streams and develop on floodplains, both of which, if preserved, would provide natural buffers to storm surge and flooding. As the impacts of climate change worsen, the combination of increasing storm intensity, land subsidence, and sea level rise are expected to exacerbate these problems (USACE 2015).


*Figure 21. High-intensity development in the vulnerable coastal area of Norfolk (VSLCD).*

Together with USACE, Norfolk will undertake a Flood Risk Management Study to investigate flood risk reduction strategies that will increase the city's resilience to future storms and mitigate the high economic, social, and environmental cost of frequent flooding. The study will examine the efficacy of both structural and nonstructural measures to mitigate flooding. Structural measures include berms/levees, floodwalls and bulkheads, flood/tide gates, road/rail raises, shoreline stabilization features, and stormwater system improvements. Nonstructural strategies include building codes, rezoning, relocation of homes, emergency plans, hazard mitigation plans, flood warning systems, and more. One can see from these planning strategies that urban flood risk management is directly linked to and embedded in urban planning and land administration, and high-resolution land cover data will improve the accuracy of such measures.

## 3.5 Applications for Planning District Commissions

For PDCs lacking access to high-resolution land cover data, the VSLCD presents a new opportunity to integrate such data into planning efforts, as the NLCD has been found to be too coarse for most planning applications and thus used sparingly. Many PDCs have been forced to digitize land cover data from aerial photographs to satisfy their data needs. PDCs may also see a value in having access to a single consistent product across jurisdictional boundaries, as there is often a large disparity in both quality and availability of data across various localities.

Many PDCs will find opportunities to improve the accuracy and quality of ongoing planning projects by replacing the 30-meter NLCD with the VSLCD. The Southside PDC will transition the new product into green space planning and enterprise zoning, which both previously relied on the inadequate NLCD (Andy Wells, e-mail to Brandon Wheeler, May 13, 2016). Any PDC involved in a green infrastructure project or in conservation planning will find the VSLCD to be a critical resource for identifying prime farmland and critical habitat. For example, the Rappahannock-Rapidan Regional Commission (RRRC) will use the VSLCD to update and improve on its Prime Agricultural Lands Model (Figure 22) that was developed using the 2011 NLCD as part of a regional green infrastructure planning effort (Patrick Mauney, phone call with Brandon Wheeler, May 13, 2016). As described in section 3.3, HRPDC utilizes land cover data to identify large areas of contiguous forest for the region's effort to protect conservation corridors (Sara Kidd, e-mail to Lyndsay Duncan, April 22, 2016). Other HRPDC efforts that will be enriched by the VSLCD include modeling stormwater runoff and TMDLs, source water protection planning, and water supply planning. The Richmond Regional PDC (RRPDC) will be able to improve the accuracy of the Richmond Green Infrastructure Project by updating it using the one-meter VSLCD. RRPDC will also update its %ISA estimates in addition to its land use maps, which are used to study growth patterns in the region and to support Long Reach Transportation Planning (Sarah Stewart, conversation with author, May 4, 2016).

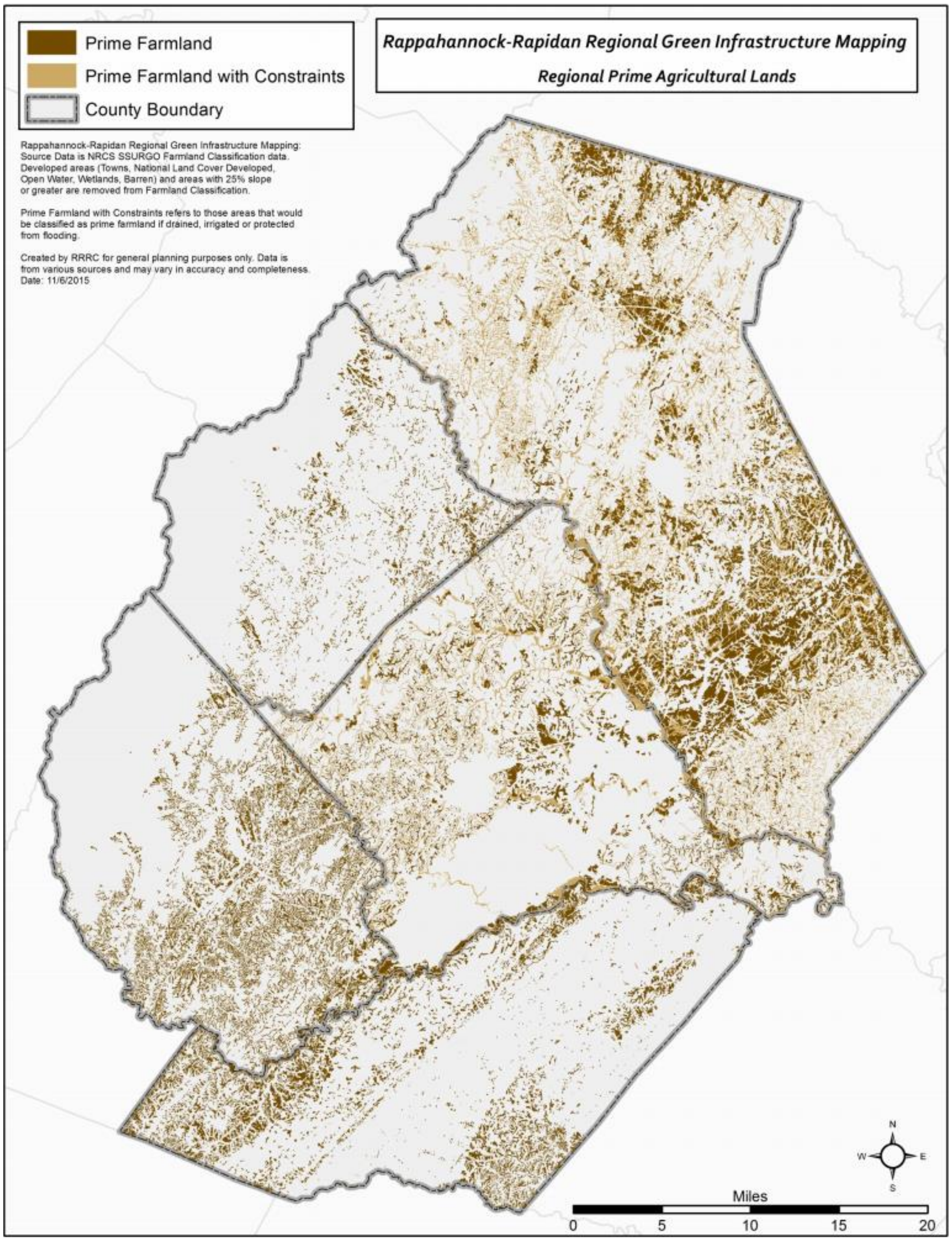


*Figure 22. Rappahannock-Rapidan Regional Prime Agricultural Lands. From RRRC.*

New planning projects that require up-to-date, high-resolution data may become possible with the availability of the VSLCD. Both the RRPDC and the HRPDC plan to conduct riparian buffer analysis with the help of the VSLCD (see section 1.4.2). The Roanoke Valley-Alleghany Regional Commission (RVARC) as well as the New River Valley Regional Commission (NRVRC) plan to use the VSLCD to conduct county-level land cover change analyses (see section 4.1). The NRVRC sees a value in the VSLCD for tracking land development as well as for natural disaster management while periodic updates to the VSLCD would facilitate comparisons over time in both of these applications (Zachary Swick, e-mail to Brandon Wheeler, May 25, 2016). Several PDCs are interested in conducting urban tree canopy analyses, which support the work of urban forestry programs. An extensive tree canopy in urban areas can aid in meeting TMDLs, planning for sustainability, and dealing with climate change (Sarah Stewart, conversation with author, May 4, 2016). The RVARC's Urban Tree Canopy project will make use of the VSLCD to support the development of urban tree canopy data for the Roanoke Valley region (Matt Miller, e-mail to Brandon Wheeler, May 23, 2016). A further potential use for the VSLCD includes climate change adaption planning in which the regional effects of sea level rise and storm surge will be mapped in an upcoming joint land use study among the Navy and the cities of Norfolk and Virginia Beach (Sara Kidd, e-mail to Lyndsay Duncan, April 22, 2016).

# 4. Capabilities for Change Detection

NLCD datasets are updated primarily using change detection analysis, comparing previous releases to more current Landsat data. This not only allows updates to be released more quickly and at significantly lower cost, but also readily provides change detection statistics for each class at a reasonable level of accuracy. A similar solution is available to the VSLCD by utilizing VBMP imagery in change detection analysis. As long as the VBMP continues to be updated for each side of the state biannually, the VSLCD could be updated on a regular basis, providing a powerful tool for assessing land cover change within Virginia while also prompting subsequent studies of the drivers and impacts of that change. Localities interested in monitoring the spatial and temporal aspects of phenomena such as urban development, rural decline, or wetland loss have the option to use the VSLCD as an input in change detection by comparing it to older datasets and/or imagery. An add-on project for change detection using the VSLCD is currently underway, provided through VGIN, and scheduled to be completed in fall 2017. This project will use an overlay analysis approach to conduct a backward change detection comparing the VSLCD product to a subset of classifications extracted from 2006/2007 VBMP imagery and will specifically focus on where forest and agricultural cover have become urbanized or turned to water as well as where forest has turned to agricultural cover and vice versa. The forest and agricultural classifications will be extracted from the earlier imagery and then overlaid with the VSLCD. Features that have changed will be aggregated and reported with acreage information for each county in the state. Figure 23 and Figure 24 demonstrate an example of this process. Figure 23 compares VBMP imagery for the same area in 2007 and 2013, while Figure 24 shows the results of a change analysis of the land cover present in the two images. The areas in yellow indicate forest cover that has been converted to agricultural cover between 2007 and 2013, while blue-green indicates where forest has been converted to water. For more details, see the Land Cover Add-On Technical Plan of Operations provided on the Virginia GIS Clearinghouse with the VSLCD downloadable product. As datasets based on newer imagery become available in the future, the VSLCD can form the basis for forward change detection analysis that can investigate land cover changes that have occurred since 2013/2016 imagery acquisition.

*Figure 23. VBMP imagery of a portion of Mecklenburg County in 2007 (left) and 2013 (right).*

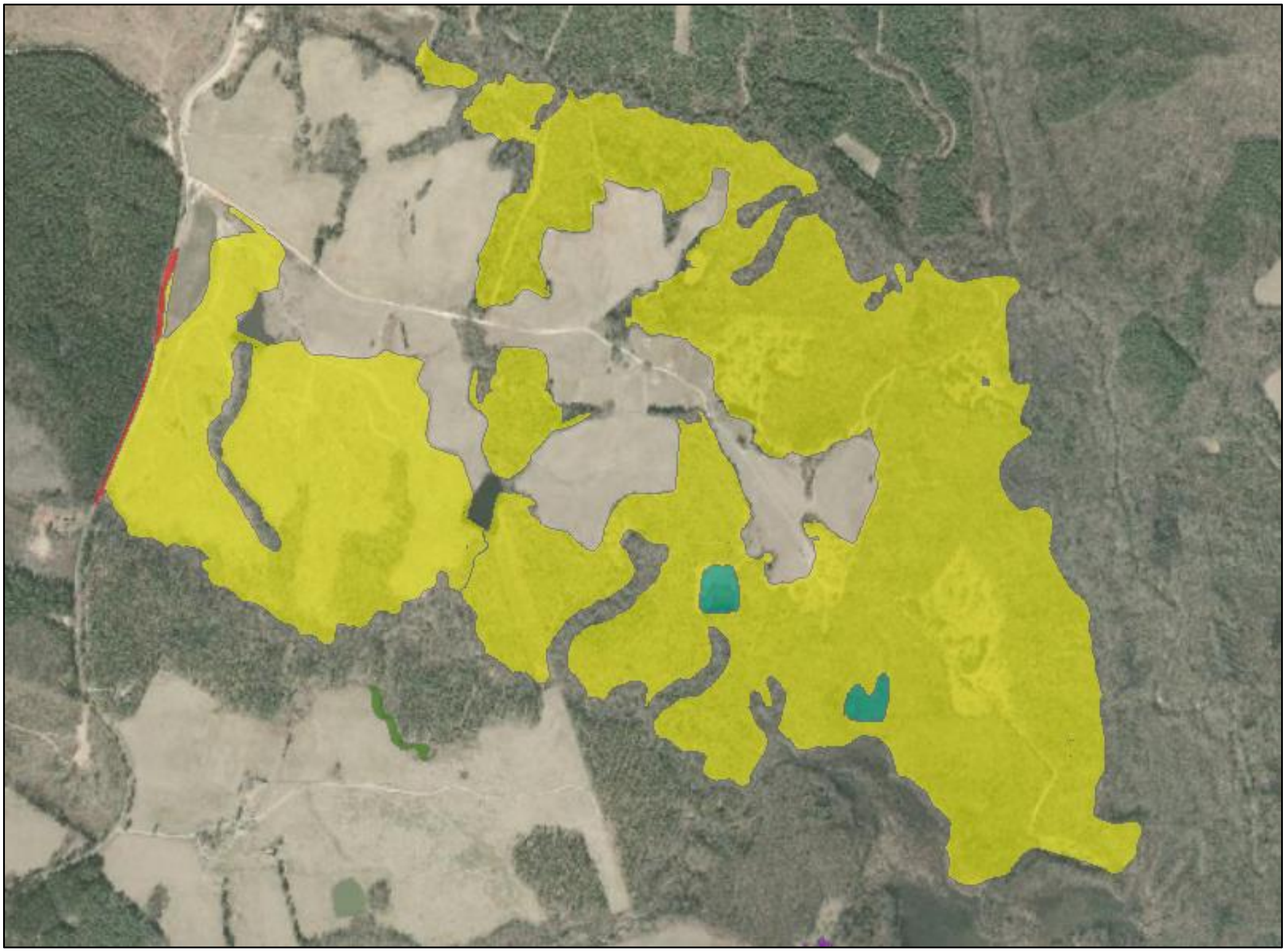

*Figure 24. Yellow indicates forest cover that was converted to agricultural cover, and blue/green where forest became water, between 2007 and 2013 in Mecklenburg County.*
*This was derived from land cover datasets based on the VBMP imagery shown in Figure 23.*

## 4.1 Case Study: Coastal Change Analysis Program

The Office for Coastal Management at NOAA maintains a land cover product called the Coastal Change Analysis Program (C-CAP) covering all coastal intertidal areas, wetlands, and adjacent uplands of the coastal contiguous United States in order to better understand the impacts of land use changes in these areas. A [30-meter product]() is updated every five years while [one- to five-meter products]() are available for select areas. Several datasets are derived from these initial products. A 30-meter [Forest Fragmentation]() dataset assesses and monitors the extent of forest fragmentation and potential habitat impacts. This type of analysis provides evidence that despite their ecological importance, large intact forests are increasingly vulnerable to development pressures caused by urban and suburban sprawl. Since the 30-meter C-CAP product is regularly updated, regional land cover changes such as forest loss, agricultural decline, and urban expansion can be mapped and monitored over time via change analysis. These change analysis studies have indicated that coastal areas are experiencing significantly faster land cover change compared to the rest of the nation. Between 1996 and 2010, the majority of forest losses could be attributed to timber harvesting while development was responsible for most wetland losses (NOAA n.d.). The high-resolution land cover datasets provide insight to land cover change at a local level. This is analogous to what the VSLCD can provide, either when compared to the C-CAP, other existing local land cover datasets, or to future iterations of the VSLCD itself. The detailed C-CAP classifications can be collapsed to match the VSLCD classifications in order to facilitate comparisons between the two datasets (Figure 25).

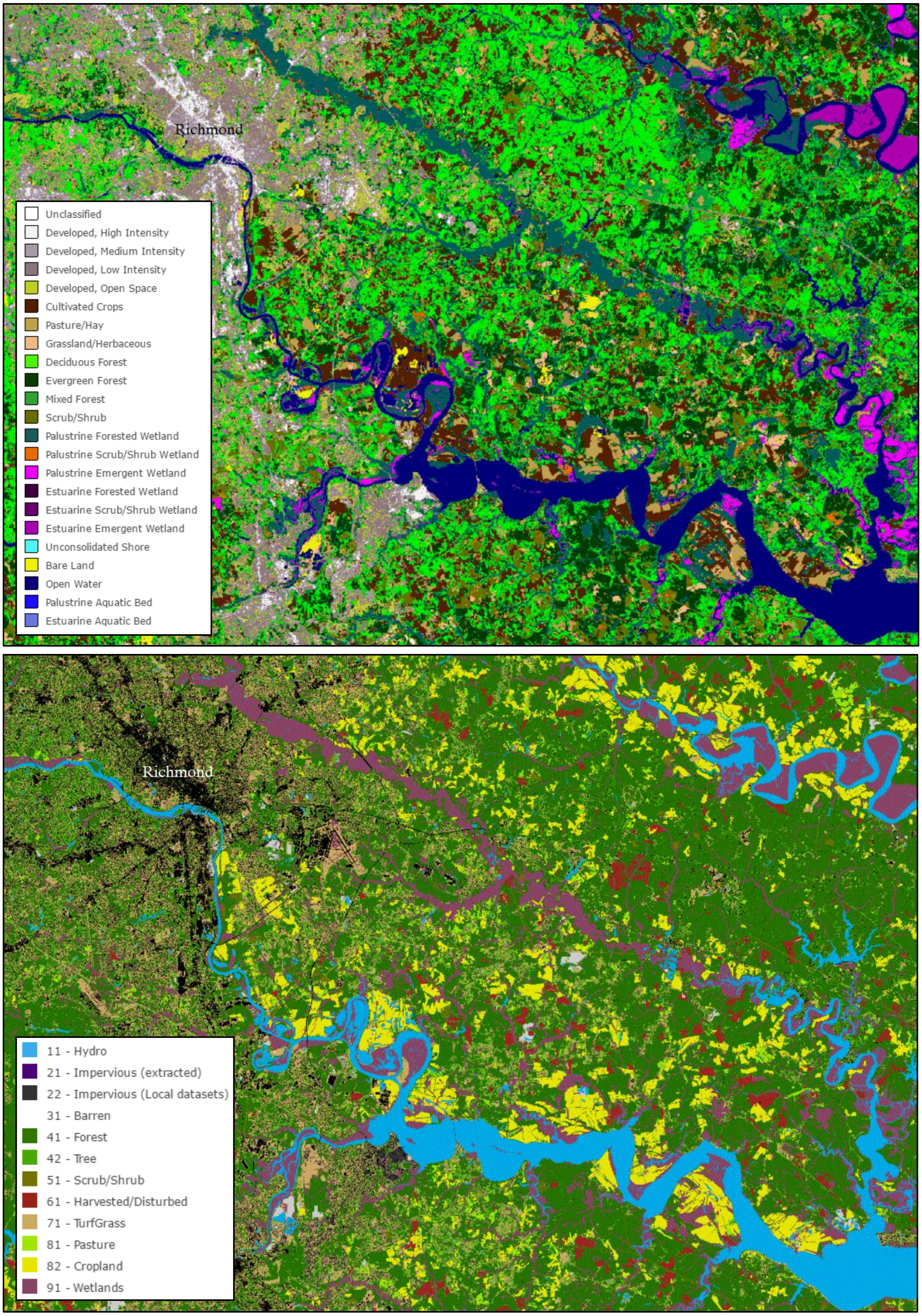


*Figure 25. Land cover for parts of Virginia's Coastal Plain near City of Richmond.*

*C-CAP (top), VSLCD (bottom).*

### 4.2 Drivers of Land Cover Change

Investigating the drivers of land cover change may provide insight for predicting future change under various scenarios. The drivers of forest loss are well studied, as are the underlying processes of agricultural decline (van Vliet, et al. 2016). The phenomenon of main interest today is probably urban expansion, which can be modeled using impervious surface data. Several studies have found urban expansion to be strongly correlated with wetland loss and agricultural decline (van Asselen, et al. 2013, van Vliet, et al. 2016). In one change detection study, population dynamics in St. Louis were found to drive suburban sprawl in conjunction with loss of both the urban center and agricultural land (Maimaitijiang, et al. 2015). Ahmad et al. (2016) found that the development of a rapid transit system promoted land cover change associated with suburbanization and urban decentralization in Delhi. López et al. (2001) analyzed land cover data to quantify 35 years of urban growth in Morelia, Mexico and then projected future growth for the next 30 years using regression analysis. The observed urban expansion in conjunction with cropland loss was attributed to migrations from rural areas into the city after agricultural products experienced a price drop. Because development in Morelia is occurring rapidly and without planning, the urban area is highly fragmented by vacant lots (López, et al. 2001).

Many studies however look beyond urbanization. Maimaitijiang et al. (2015) also found that reforestation efforts, particularly on abandoned agricultural land, was driving a net gain in forest cover in the St. Louis area. Another study found that logging activities correlate to shifts in forest composition from mixed to primarily evergreen (English 2011). Studies of grassland losses have identified ownership changes, privatization, fragmentation, and population growth as the main explanations (van Vliet, et al. 2016). Knowledge of what processes drive land cover change will allow for improved land management in the future.

### 4.3 Impacts of Land Cover Change

Following a change detection analysis, subsequent studies may investigate various environmental, social, or economic impacts of land cover changes. Change analysis studies have determined that land cover changes such as agricultural development, urban expansion, and timber harvesting are the most important factors driving various environmental phenomena such as wetland conversion, deforestation, desertification, saltwater intrusion, and biodiversity loss (van Asselen, et al. 2013, English 2011). For example, a decline in various indicators of environmental quality was observed over a 25-year period due to land use/land cover change in residential areas in the UK (Pauleit, Ennos and Golding 2005). As impervious surface cover expanded and greenspace declined, surface temperatures increased, surface runoff increased, and biodiversity indicators decreased.

Monitoring land cover change can inform risk management. Land cover change in Morelia, Mexico was analyzed against slope data, and it was found that substantial urban development occurred on steep slopes, endangering parts of the city to landslides and rock-falls (López, et al. 2001). In the southeastern US, the encroachment of rural development into forestland increasingly puts people and property in danger of wildfires (Zhang, He and Yang 2008). These studies present merely a few examples of the huge potential for research afforded by change detection analyses derived from the VSLCD.

## Summary

This paper has covered a variety of applications for the VSLCD, provided background on the development of the project, summarized current state and local needs for these data, and introduced practical applications for land cover data through a series of case studies. This is in no way an exhaustive study, but is intended to serve merely as a starting point for high-resolution land cover data use cases. Similarly, not all potential users are represented in the preceding case studies. Because this data is publicly available, citizens, such as students and teachers, may access and manipulate the data to answer their own questions.

Prior to the release of the VSLCD, the 2011 NLCD served as the most up-to-date source for statewide land cover data in Virginia. While the NLCD serves as a useful component in land cover modeling, the increased level of detail and accuracy represented by the VSLCD is expected to strengthen the utility of land cover data for applications that include impervious surface estimation, stormwater modeling, urban planning, green infrastructure planning, and riparian buffer analysis, among many more. When combined with external spatial data, the VLCD offers opportunities for further subclassifcation to enhance its usefulness. The potential users of the VSLCD range from federal institutions to state departments, local governments, and non-governmental organizations. This dataset will serve as an input in environmental models such as CBP's Watershed Model and DCR's Virginia Natural Landscape Assessment. Change detection becomes possible when the VLSCD is compared to older imagery, and change monitoring may continue into the future if the VSLCD is updated regularly along with the VBMP imagery.

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